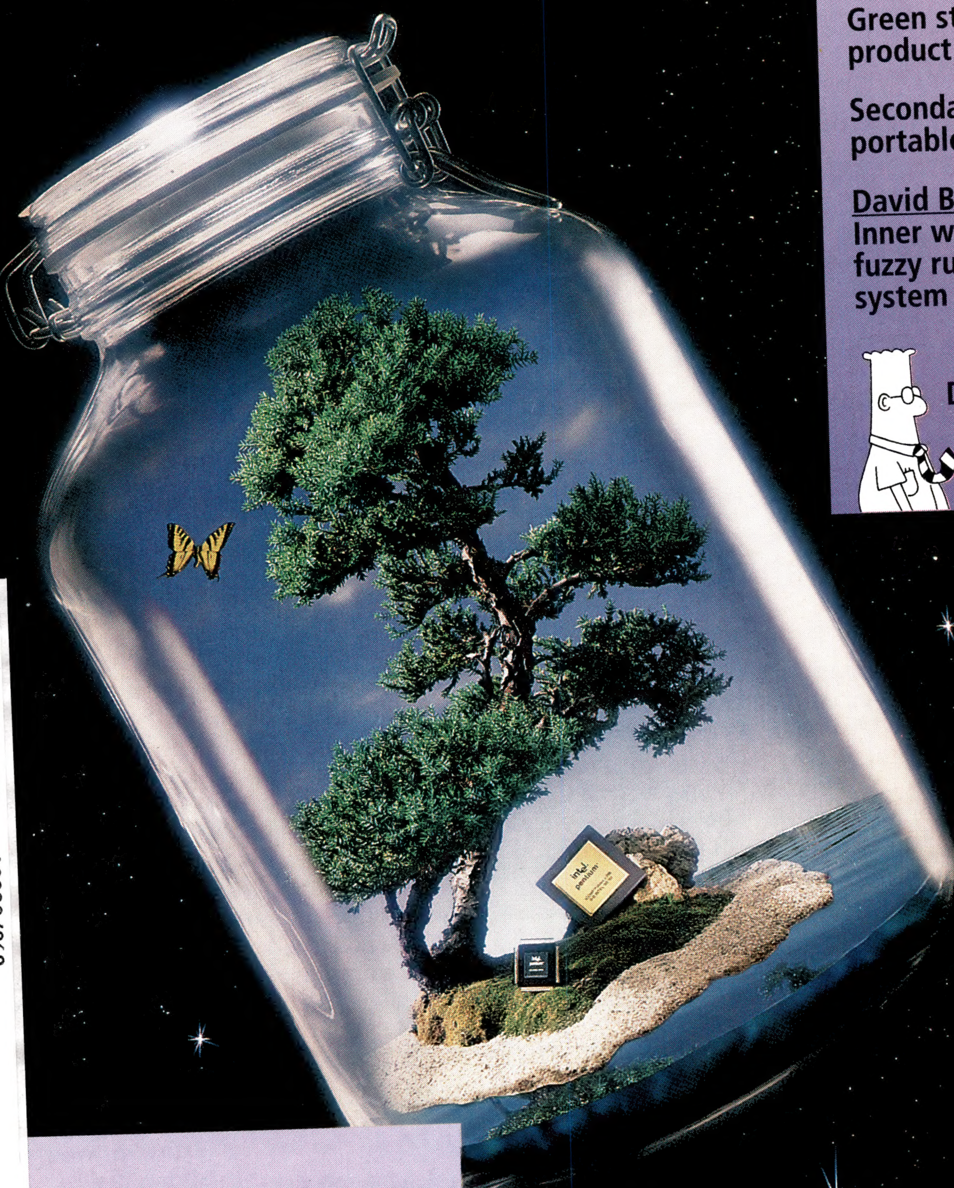
EUROPEAN EDITION

EDN®

THE DESIGN MAGAZINE OF THE ELECTRONICS INDUSTRY

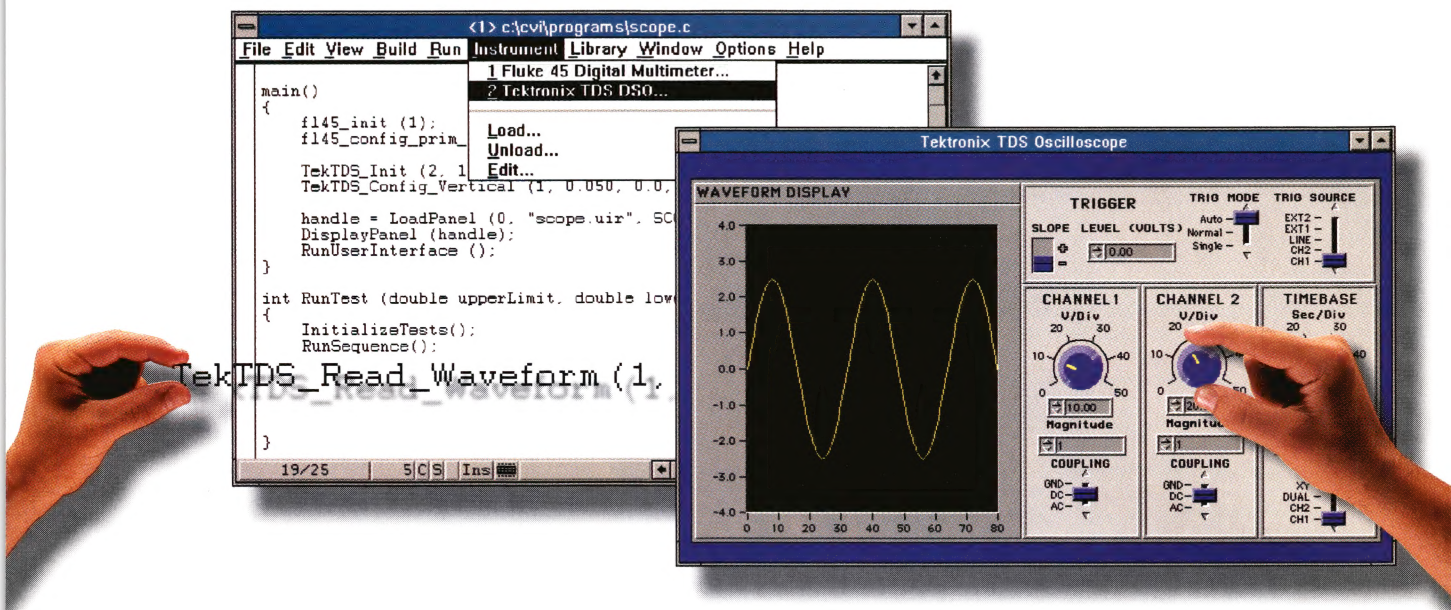
NOVEMBER 10, 1994



CPUs, chip sets, and BIOS join to green your PC pg 44

A CAHNERS PUBLICATION

Get Interactive!



LabWindows®/CVI

The Programming Power of C, the Development Ease of BASIC

Discover a new approach to C programming for instrumentation – the interactive approach. With LabWindows/CVI, you harness the power and flexibility of ANSI C through easy-to-use interactive code-generation tools. LabWindows/CVI is an ANSI C programming environment with GUI objects, instrumentation libraries, data analysis functions, and utilities specifically designed for data acquisition and instrument control systems.

Interactive Development

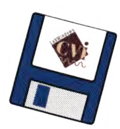
As an instrumentation system developer, you need quick results. With LabWindows/CVI function panels, you can interactively acquire data from plug-in boards, or control GPIB, VXI, and RS-232 instruments without writing a single line of code. Then, use function panels to generate code automatically and jump start your programming efforts.

C Programming Flexibility

LabWindows/CVI is more than just interactive tools to make programming easier. With LabWindows/CVI, you have the power and flexibility of ANSI C at your fingertips, so you can be assured that it is fast enough, powerful enough, and flexible enough to get your job done. Plus, the integrated LabWindows/CVI environment has the advanced editing, compiling, and debugging tools you expect. Combining the power of ANSI C with an interactive, BASIC-like development environment results in true programming productivity.

You don't have to sacrifice ease of use when you program in a standard language anymore.

Call for a FREE LabWindows/CVI demo disk
(800) 433-3488
(U.S. and Canada)



NATIONAL INSTRUMENTS®
The Software is the Instrument®

See us at Comdex, booth S785

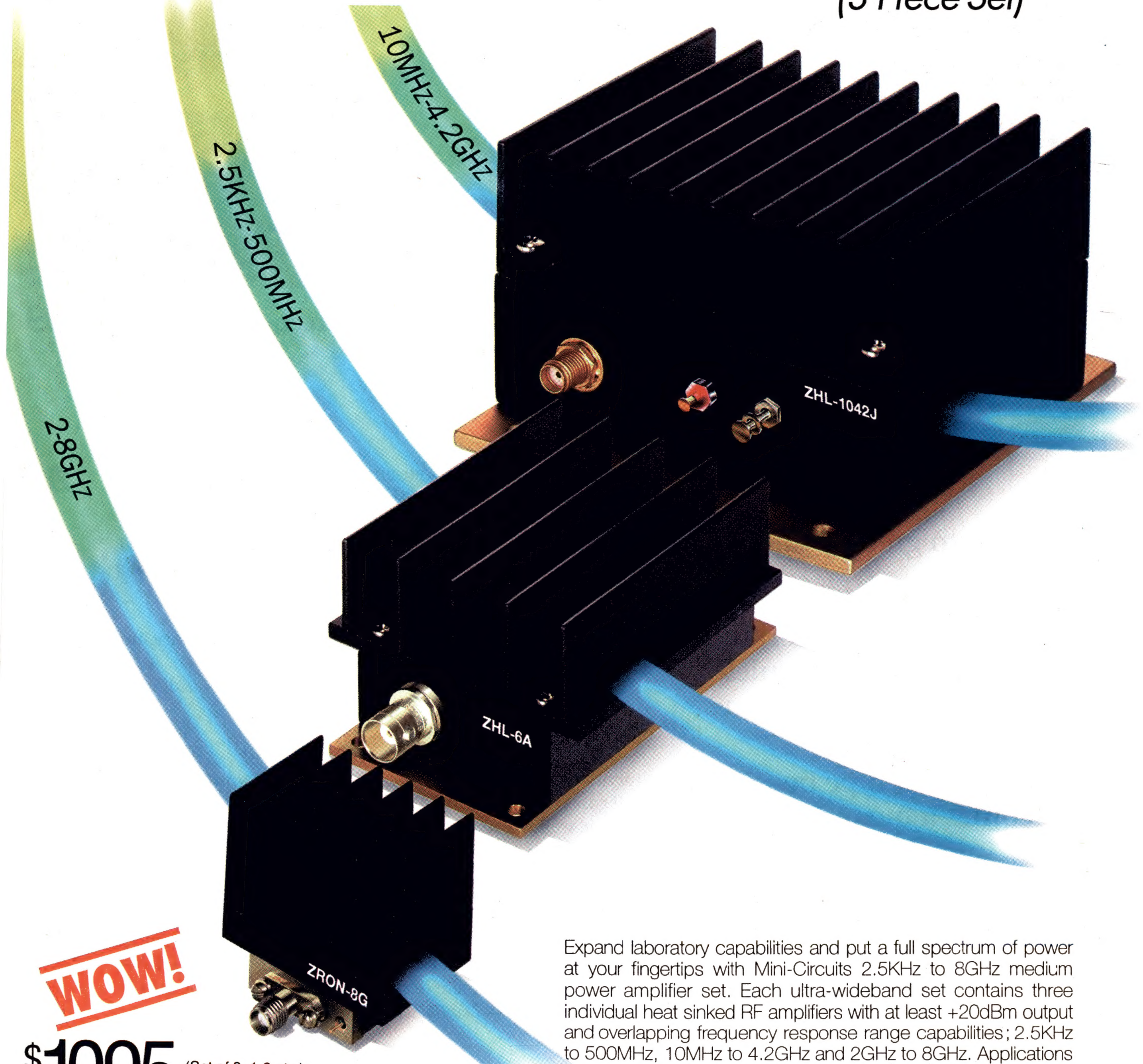
6504 Bridge Point Parkway • Austin, TX 78730-5039 • Tel: (512) 794-0100 • 95 (800) 010 0793 (Mexico) • Fax: (512) 794-8411

Branch Offices: **Australia** 03 879 9422 • **Austria** 0662 435986 • **Belgium** 02 757 00 20 • **Canada** 519 622 9310 • **Denmark** 45 76 26 00 • **Finland** 90 527 2321 • **France** 1 48 14 24 24 • **Germany** 089 741 31 30 **Italy** 02 48301892 • **Japan** 03 3788 1921 • **Netherlands** 03480 33466 • **Norway** 32 848400 • **Spain** 91 640 0085 • **Sweden** 08 730 49 70 • **Switzerland** 056 27 00 20 • **U.K.** 0635 523545

CIRCLE NO. 158

2.5KHz-8GHz AMPLIFIERS

(3 Piece Set)



WOW!

only **$1095** (Set of 3 1-9 qty.)

+20dBm Power Output, 20dB Gain

Model :	Freq. (MHz)	Gain (dB)	Power Output, dBm @ 1dB Compression	DC Power Volt V	DC Power Current mA	Conn. Type	Indiv. Price ($) (1-9 qty.)
ZHL-6A	.0025-500	21	+23	+24	350	BNC	199
ZHL-1042J	10-4200	25	+20	+15	330	SMA	495
ZRON-8G	2000-8000	20	+20	+15	310	SMA	495

Set of 3 Amplifiers # KZHL-318: $1095 (1-9 qty.)

Expand laboratory capabilities and put a full spectrum of power at your fingertips with Mini-Circuits 2.5KHz to 8GHz medium power amplifier set. Each ultra-wideband set contains three individual heat sinked RF amplifiers with at least +20dBm output and overlapping frequency response range capabilities; 2.5KHz to 500MHz, 10MHz to 4.2GHz and 2GHz to 8GHz. Applications for these amplifiers include increasing the signal levels to power meters, spectrum analyzers, frequency counters and network analyzers as well as boosting signal generator outputs.

You can buy these amplifiers individually at Mini-Circuits already low prices, or own the full spectrum set for the money saving price of only $1095 (1-9 qty.) ! To order from stock with a guarantee to ship within one week, call Mini-Circuits today !

Mini-Circuits...we're redefining what VALUE is all about!

Mini-Circuits®

P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661

r detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM • MINI-CIRCUITS' 740- pg. HANDBOOK.

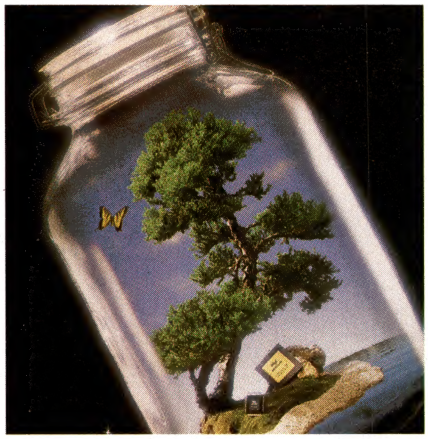
F 185 Rev Orig

CUSTOM PRODUCT NEEDS...*Let Our Experience Work For You.*

CIRCLE NO. 149

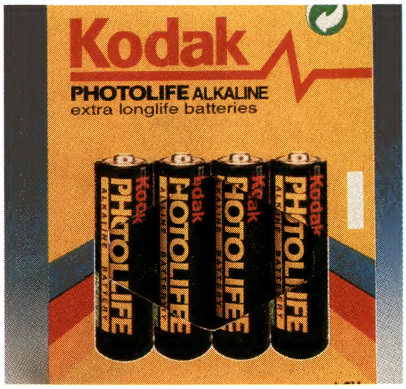
EDN NOVEMBER 10, 1994

A Cahners Publication/Volume 39, Number 23



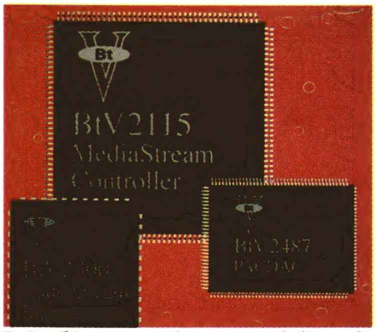
COVER STORY

GREEN YOUR PC
Cover photo courtesy Intel Corp; Digital photography by Richard Wahlstrom Photography Inc. **44**



EDN DESIGN FEATURES

Out in Front



EDN Design Ideas

EDN Columnist

EDN Products

EDN Departments

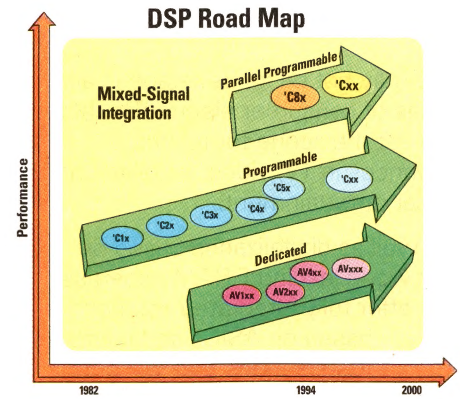
EDN® (ISSN 0012-7515, GST Reg. #123397457, C.P.C. Intl Pub Mail #0280844) is published 38 times per year, bi-weekly with one additional issue per month, by Cahners Publishing Company, A Division of Reed Publishing USA, 275 Washington Street, Newton, MA 02158- 1630. Robert L. Krakoff, Chairman and Chief Executive Officer; Timothy C. O'Brien, Executive Vice President/Finance and Administration; Michael Wisner, Senior Vice President/General Manager, Boston Division; Michael Wisner, Vice President/Publishing Director. Circulation records are maintained at Cahners Publishing Company, 8773 South Ridgeline Blvd., Highlands Ranch, CO 80126-2329. Telephone (303) 470-4445. Second-class postage paid at Littleton CO 80126 and additional mailing offices. **POSTMASTER: Send address changes to EDN®, PO Box 7500, Highlands Ranch, CO 80126-7500.** EDN® copyright 1994 by Reed Publishing USA. Rates for non-qualified subscriptions, including all issues: US, $140.00 one year, $238.00 two year; Canada, $209.00 one year, $355.00 two year (includes 7% GST, GST# 123397457); Mexico, $195.00 one year, $332.00 two year; Foreign surface $245.00 one year, $417.00 two year; Foreign air expedited surcharge add $152.00 one year, $304.00 two year. Except for special issues where price changes are indicated, single copies are available for $10.00 US and $15.00 foreign. Please address all subscription mail to EDN®, 8773 South Ridgeline Blvd., Highlands Ranch, CO 80126-2329. EDN® is a registered trademark of Reed Properties Inc., used under license.

(Printed in USA)

Move your ideas ahead faster with TI's DSP-based solutions.

Today, digital signal processors are being designed into more of tomorrow's breakthrough products for a competitive edge. And the DSP Solutions that are in more designs are those made by Texas Instruments.

Twelve years long, fifteen thousand strong. Experience. It comes from 12 years of helping designers extend their reach to create more advanced products with DSPs. And with a track record of supporting 15,000 customer products from various markets, we understand what you're looking for in a DSP Solutions supplier.



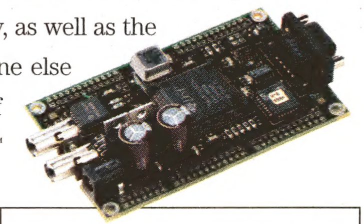
From $3 to 2 billion operations per second, the TMS320 family has your solution. Technology. No other DSP supplier has the breadth of price/performance solutions that get you to market faster. With a better product.

We have the product you need. From our dedicated solutions, to our customisable, application-specific or general-purpose fixed- and floating-point programmable devices, to our 2-billion-operations-per-second parallel programmable TMS320C80 MVP. You'll also find a suite of mixed-signal products to complete your DSP design solution, such as our families of converters and interface circuits.

And no one has more worldwide DSP manufacturing capability. So, whatever you're working on today, or thinking about for tomorrow, think of TI as the one to help.

Development support how you need it. When you need it. At TI, we provide you with the most highly acclaimed DSP support program. Including off-the-shelf, world-class development tools, a hot line staffed by DSP experts, a 24-hour bulletin board, real-world application notes, DSP-design textbooks and the industry's largest network of third-party developers, including the TMS320 Software Co-op.

Our DSP information will get you going. Fast. No one makes it easier to design with DSPs than TI. Because no one else has the experience and the technology, as well as the support. And no one else has the power of Total Integration.™ For more information, simply circle the number below on the reader service card.



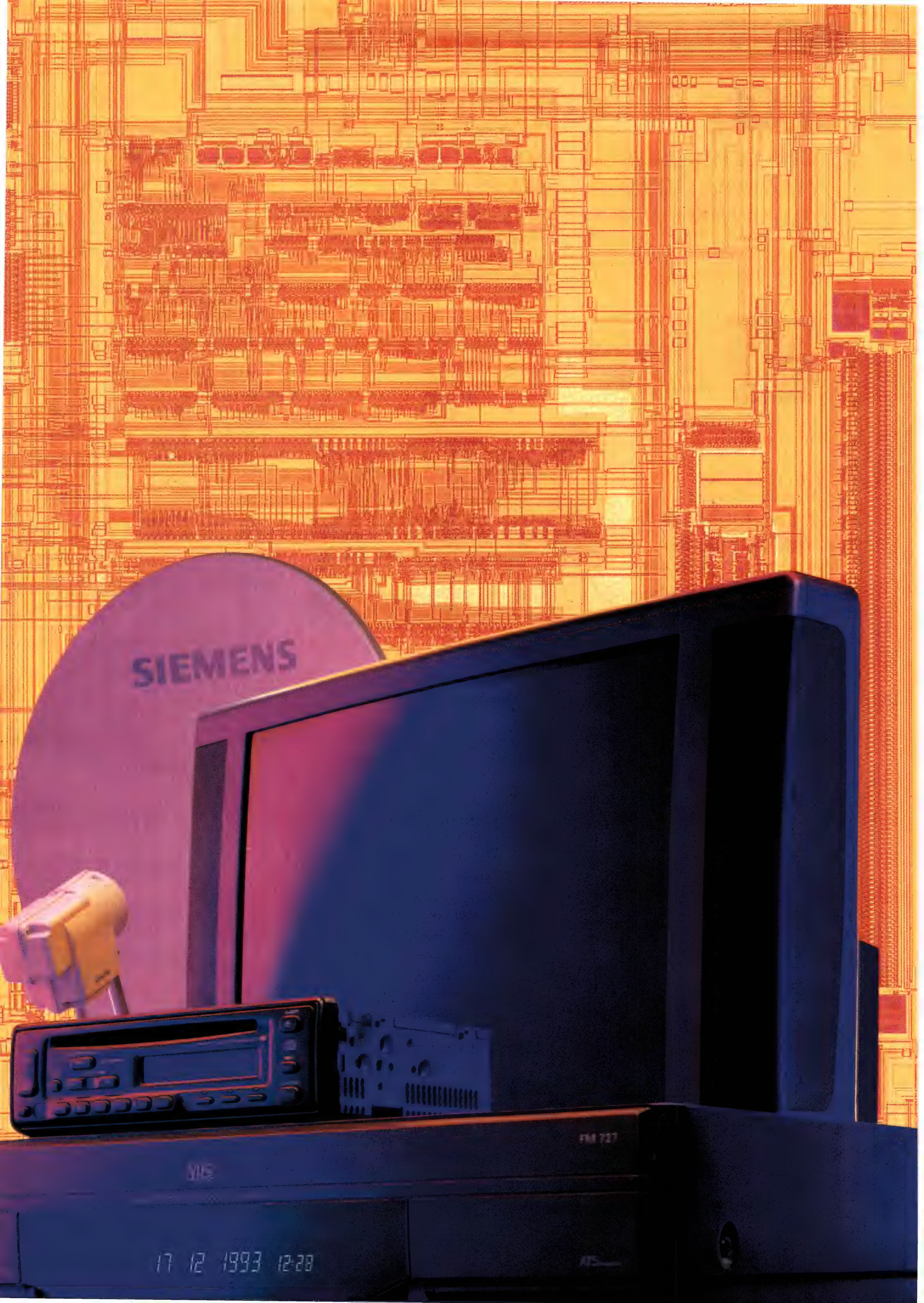
For only $99, you can get the TI DSP Starter Kit. It offers you a low-cost, easy-to-use tool for initial understanding of TI TMS320 DSPs. And includes board, assembler and debugger software, sample programs and documentation.

E X T E N D I N G   Y O U R   R E A C H™

TEXAS INSTRUMENTS

03-8856P
SPZE0ED411R

CIRCLE NO. 209


SIEMENS
17 12 1993 12:28

Fluke's New Autoranging DSO. Check this amazing combination.

FLUKE
Now Incorporating
Philips T&M

INTRODUCTION PRICE
NLG 7.750,-*
CALL NOW!

For the price in your country, contact your local sales office.

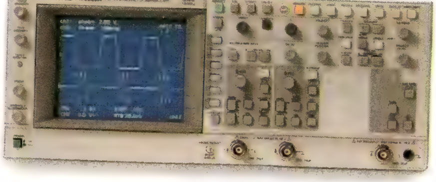
uke's new 2 channel, 100 MHz Autoranging SO, the PM3380A, packs more useful features an any other scope in its price class. Which akes it amazing value-for-money. Check the atures for yourself.

√ **Autoranging.** Keeps you going with instant results all the time! Just probe your circuit and watch the scope work for you, automatically and continuously.

√ **Analog scope built-in.** Just push the yellow button and your DSO becomes a true analog scope - a valuable second opinion on your DSO picture, instantly!

√ **Sampling rate equivalent to 10 GS/s!** Thanks to full-time resolution at fast timebase settings.

√ **True digital peak-detection.** With oversampling to catch those elusive signal components.



Copyright 1994 Fluke Corporation. All rights reserved.

√ **Waveform on the external trigger input.** It's almost another channel!

√ **And more** Including glitch triggering, triggered delayed timebase, up to 16k memory per channel, glitch capture, closed case calibration, built-in video line counter, programmable probes and RS-232C interface standard.

The CombiScope PM3380A. Call for the full picture.

Austria (1) 61410-0, **Belgium** 02 - 331 27 77, **Denmark** 43 44 1900, **Finland** (90) 5026 600, **France** (1) 4896 6363, **Germany** (0561) 95940, **Great Britain** (0923) 240511, **Greece** (01) 4894911, **Ireland** (061) 330333, **Italy** (02) 268 4341, **Netherlands** (040) 644100, **Norway** (22) 65 34 00, **Portugal** (01) 795 1712, **Spain** (91) 804 2750, **Sweden** (08) 751 02 30, **Switzerland** (01) 730 3310.

For countries not listed, call **Fluke Europe BV**, tel. +31 40 644 200 or fax +31 40 644 222.

FLUKE®

CIRCLE NO. 162

EDN BUSINESS STAFF

Home Office: 275 Washington St, Newton, MA 02158. EDN Bulletin Board: (617) 558-4241; MCI: EDNBOS; fax (617) 558-4470; phone (617) 964-3030.

PUBLISHER **Jeffrey Patterson (617) 558-4454**

ADVERTISING SALES DIRECTOR
PAUL ROTHKOPF
(617) 558-4651

MARKETING/BUSINESS DIRECTOR
DEBORAH VIRTUE
(617) 558-4779

CUSTOM PUBLISHING SERVICES
PATRICIA TYLER, DIRECTOR
(617) 558-4526

ASSISTANT TO PUBLISHER
MARIA MCGRATH
(617) 558-4346

CONTRACTS
MURIEL MURPHY
(617) 558-4451
JULIE WAELDE
(617) 558-4250

CIRCULATION
DEBBIE BARELA
(303) 470-4000

NEW ENGLAND
CHRIS PLATT
(617) 964-3730
fax: (617) 332-7128

NEW YORK/NEW JERSEY/MID/SOUTH ATLANTIC
DIANE DRISCOLL
(203) 326-5161
fax: (203) 326-5160

IL/IN/KY/OH/TN/TX/OK/FL/SC
JOANN CANNON
(708) 635-8800
fax: (708) 635-0929

IL/MI/MN/NE/IA/KS/ND/SD/WI/MO/AL/AR/GA/MS/CANADA
JACK JOHNSON
(708) 635-8800
fax: (708) 390-2815

ARIZONA
DONNIE JONES ADAMS
(408) 243-8838
fax: (408) 345-4400

ORANGE/RIVERSIDE/SAN DIEGO COUNTIES/LOS ANGELES/
Southern CA/NV
SUSAN N GREEN
(714) 851-9422
fax: (714) 752-6867

COLORADO/WASHINGTON/OREGON
ROGER GAW
(408) 243-8838
fax: (408) 345-4400

NORTHERN CA/SILICON VALLEY
DONNIE JONES ADAMS
BETTINA MCGOWAN
ROGER GAW
(408) 243-8838
fax: (408) 345-4400

INFO CARDS/LITERATURE LINK
MELISSA BACHMAN
(617) 558-4282
fax: (617) 558-4328

RECRUITMENT
PATRICIA KENNEFICK
(617) 558-4488
(617) 630-3925

PRODUCT MART
JOANNE DORIAN
(212) 463-6415
fax: (212) 463-6404

INSIDE SALES
LISA BARRIERE
(617) 558-4361
fax: (617) 558-4328

UK
JOHN WADDELL
(011) 44 81 312 4696
fax: (011) 44 81 312 1078

NORWAY/SWEDEN/FINLAND
ROLAND NIHLMAR
LARS GRUNBERGER
(011) 46 8616 0760
fax: (011) 46 8616 0777

DENMARK
AASE KISBORG
(011) 45 33 14 9888
fax: (011) 45 33 14 9288

NETHERLANDS/BELGIUM/GERMANY ZIP CODES 0-5
ALBERT TICHELER
(011) 31 40 41 37 27
fax: (011) 31 40 42 0430

GERMANY ZIP CODES 6-7
ERHARDT EISENACHER
(02 28) 65 00 13
fax: (02 28) 65 00 76

GERMANY ZIP CODES 8-9
MARGARETHE MUNCHMEIER
(011) 49 89 222 015
fax: (011) 49 89 299 160

SPAIN
LUIS GINER
(011) 343 894 43 26
fax: (011) 343 894 88 37

AUSTRIA
SVEN KOLLENSPERGER
(011) 43 732 79 34 55
fax: (011) 43 732 79 34 58

ISRAEL
ASA TALBAR
(011) 972 35 223 621
fax: (011) 972 35 242 177

ITALY
ROBERTO LAURERI
(011) 39 2 236 2500
fax: (011) 39 2 236 4411

SWITZERLAND
ROSWITHA N BRIAND
(011) 41 1261 4690
fax: (011) 41 1251 4542

FRANCE
ALAIN FAURE
(011) 33 1 46 29 46 18
fax: (011) 33 1 40 93 03 37

HONG KONG
ADONIS MAK
(011) 852 965 1555
fax: (011) 852 976 0706

JAPAN
KAORU HARA
(011) 813 3389 1822
fax: (011) 813 3389 1761

KOREA
JEONG-GWON SEO
(011) 82 2752 4392
fax: (011) 82 2752 4394

SINGAPORE/MALAYSIA
HOO SIEW SAI
(011) 65 738 0122
fax: (011) 65 738 2108

TAIWAN
PARSON LEE
JOHN SHIH
(011) 886 2711 4833
fax: (011) 886 2741 5110

AUSTRALIA
ALEXANDRA HARRIS-PEARSON
(011) 612 299 5677
fax: (011) 612 299 6178

TURKEY
CENGIZ EREN
(011) 90 216 345 3473
fax: (011) 90 216 346 2464

CAHNERS MAGAZINE DIVISION
ROBERT KRAKOFF
President, CEO
Cahners Publishing

CAHNERS MAGAZINE DIVISION
MICHAEL WISNER
Senior VP/General Manager
Boston Division

CAHNERS MAGAZINE DIVISION
TOM DELLAMARIA
Senior VP/ Production & Manufacturing

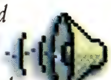
Reprints of *EDN* articles are available on a custom printing basis at reasonable prices in quantities of 500 or more. For a quote, phone Ellen Sandram, Cahners Reprint Service, at (708) 390-2773.

The Toshiba T4700CT

A notebook so powerful, it breaks the sound barrier.

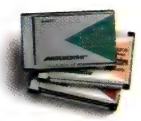
The Toshiba T4700CT can run your most intense applications or even help you run a presentation. With its SL Enhanced i486™DX2 50MHz processor, it easily handles graphics-rich programs. The built-in multimedia capabilities let you create and give breakthrough presentations anywhere, all on Toshiba's stunning color active matrix screen. With so much going for it, buying a T4700CT notebook is a very sound decision. **For a Toshiba dealer near you, call 1-800-457-7777.**

Incredible Sound: *An integrated sound system and built-in speaker let you enjoy fantastic sound whenever you want.*



The only computer you'll ever need: *The optional Desk Station IV, lets you instantly connect to your network, printer, VGA monitor, mouse, and full-size keyboard.*

Two separate PCMCIA slots: *A 16mm and a 5mm slot are your keys to expansion, —for modems, storage and more.*



A multimedia roadshow: *Headphone or external speaker port and microphone jacks make the T4700CT perfect for presentations.*

T4700CT FEATURES:
- 50MHz SL Enhanced i486™DX2
- 9.5" dia. color TFT-LCD active matrix display
- 256 simultaneous SVGA colors at 640x480 resolution
- 320/200MB HDD
- 8MB RAM expandable to 24MB
- Two PCMCIA slots (16mm and 5mm)
- VL local-bus video
- Integrated graphics accelerator
- Built-in microphone
- .WAV Audio capabilities
- Audio jacks: headphone/speaker, microphone
- NiMH battery for extended life
- QuickCharge battery recharge system
- 3.5" 1.44MB floppy disk drive
- BallPoint™ mouse with QuickPort™
- MaxTime™ Power Management system
- LCD status icon bar
- DOS™, Windows™, and Windows Sound System™ software pre-installed
- Toshiba Technical Support line: 7 days a week, 24 hours a day

intel inside

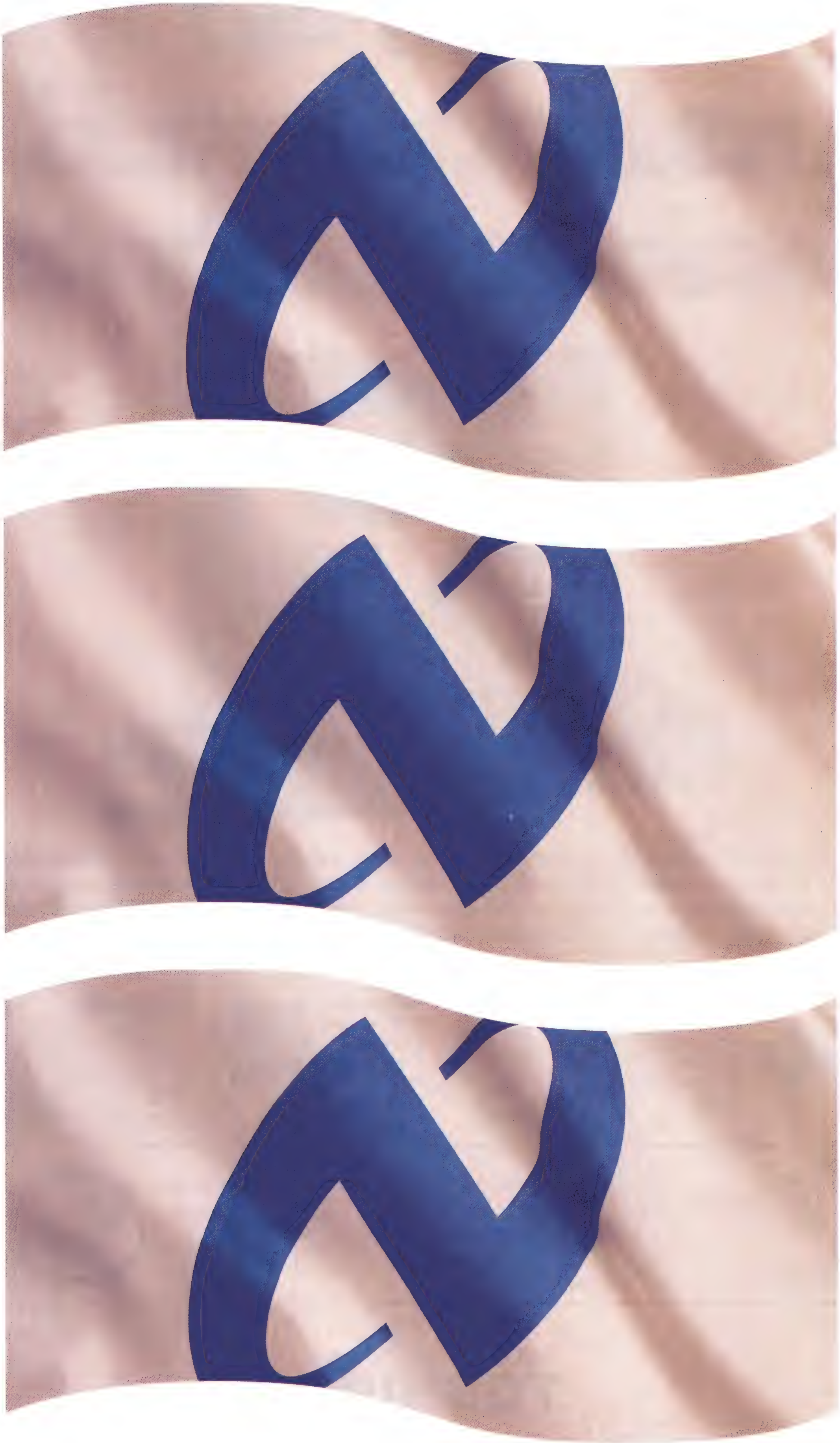
3 YEAR LIMITED WARRANTY

energy EPA POLLUTION PREVENTER

In Touch with Tomorrow

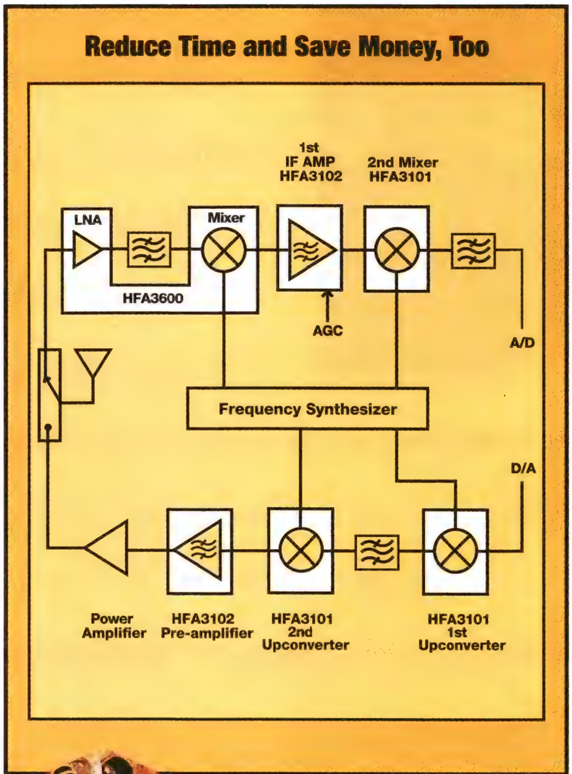
TOSHIBA

CIRCLE NO. 106



Shrink Your Wireless Design and Your Costs With Harris Silicon RF ICs.

Squeeze ounces and inches out of your next wireless project – and dollars out of your cost budget – with new RF front end ICs from Harris. Our HFA3600 LNA/Mixer gives you low-power, low-noise 900 MHz performance in 40% less space than discretes. Yet they cost just $1.82 each in 5000 piece quantities. And it's part of a whole family of high-performance, low-cost Harris silicon RF ICs, including our HFA3102 Dual Long-Tailed Pair Transistor Array and HFA3101 Gilbert Cell. They all pack a lot of product into a package that's compact – with a price to match.



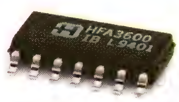
Features

HFA3600 LNA/Mixer

- Power consumption: 11mA @ 5V, 1.2 mW (sleep mode)
- LNA noise figure: 2.3dB
- Mixer OIP: +3.2dBm
- Integrated 50Ω matching
- Integrated power down function
- Just $1.82 (5000s)

HFA3102 Dual Long-Tailed Pair Transistor Array and HFA3101 Gilbert Cell

- Power Gain Bandwidth: 5 GHz
- Current gain: 70
- Excellent hfe and Vbe matching
- Just $1.80 (5000s)



As with the HFA3600, the honeybee packs a lot of potential in a small package and the rewards are inexpensively sweet.

HARRIS SEMICONDUCTOR ANSWER FAX

Call 407-724-3818 and request documents: 3655(HFA3600), 3635(HFA3101), 3663(HFA3102). Or call 1-800-4-HARRIS and ask for extension 7266.

HARRIS SEMICONDUCTOR

CIRCLE NO. 124

Media accelerator blends audio, graphics, and video data

A new media accelerator from Brooktree provides high-performance graphics, 16-bit audio, full-screen 1280×1024-pixel graphics, and 30-frame/sec video windows in a single three-chip set. The product employs a packet-based multimedia architecture, a 1-Mbyte frame buffer, a suite of software drivers, and a connection to the PCI or VL bus. Brooktree is targeting the product for both add-in cards and the next generation of Pentium-based motherboards.

The BtV MediaStream includes software-based MPEG decompression and software-based wave-table synthesis. In addition, a BtV-based PC can optionally output all-digital sound directly to consumer devices with digital input ports, including digital audio tape and CD players. The MediaPacket architecture converts all multimedia data inputs, including sound, into data packets that a local bus transmits and processes.

The product comprises the BtV2115 MediaStream controller, an audio I/O-controller chip, and a packetized-data DAC (PACDAC) D/A converter that provides graphics and mixing capabilities. Because the PACDAC resides in the back end of the subsystem, video remains in its smallest native format until it passes through the MediaBuffer, a central unified buffer. This approach reduces memory, bandwidth, and quality problems below those of systems that scale up the video before sending it to the frame buffer.

The BtV2115 MediaStream controller provides graphics-user-interface acceleration (Blt, line, draw, pattern fill) plus central video-in and audio-I/O control. An optional BtV VideoStream decoder allows video capture. In this mode, the BtV MediaStream subsystem handles all NTSC/PAL/S-video sources. Price for sample quantities of the chip set is $95. Production quantities will be available in the second quarter of next year.—by John Gallant

Brooktree Corp, San Diego, CA, (800) 228-2777.

Circle No. 460

Brooktree's BtV MediaStream accelerates audio, graphics, and video in multimedia applications.

SPARC upgrade hits 90 MHz

A confluence of technologies allows Ross Technology to offer SPARC-system users upgrades that can replace 40- and 60-MHz CPUs with as many as four 90-MHz CPUs. The technologies include a three-layer-metal, 0.5-μm, 3.3V CMOS process from parent company Fujitsu, the HyperSPARC architecture, and a multi-die packaging technique using silicon substrates. Together, the technologies allow Ross to pack a CPU, a chip set, and a 256-kbyte cache into a 131-pin PGA, enabling SPARCstation M-bus modules to contain two CPUs each. The modules run at the bus-interface speed of the host system and provide their own 90-MHz clock for the CPU. SPARCstation 10 and 20 users and SPARCserver 630/70/90 users can use two modules, bringing as many as four CPUs into play. The upgrades range in price from $5141 to $17,870 and are SCD-compliant.—by Richard A Quinnell

Ross Technology Inc, Austin, TX, (800) 774-7677. Circle No. 461

Low-cost logic analyzer targets scope users

One way to characterize HP's 54620A is to call it a $2995, 16-channel logic-timing analyzer for people who have always done digital troubleshooting with a scope. Many people have found that learning to use a logic analyzer is simply too time-consuming. So they continue to use a scope, even though, once they became familiar with the logic analyzer, they could get the job done much faster.

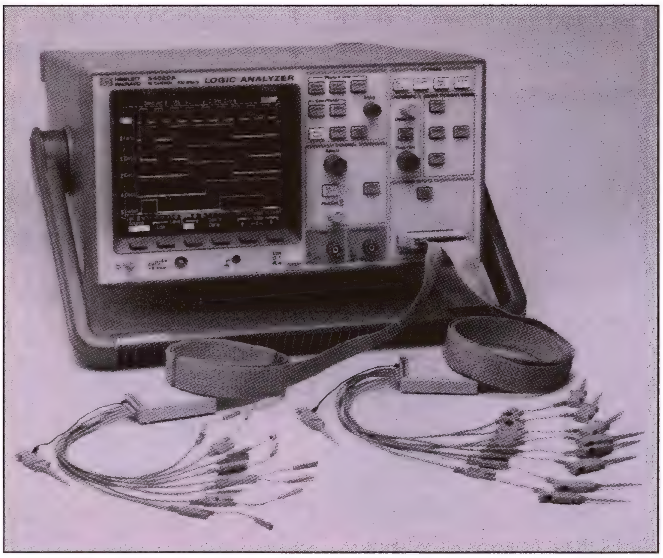
HP bases the instrument's design on that of the highly successful 54600 family of low-cost digital storage oscilloscopes. After extensive market research, the designers stripped away some of the more arcane features of high-performance logic analyzers. The result is a unit that—at its fastest sweep speed—takes 500M samples/sec (2-nsec resolution), captures 3.5-nsec glitches at any sweep speed, offers a delaying sweep and split-screen display like those familiar to most scope users, and includes a triggering system that is both flexible and easy to understand. The analyzer triggers on signal edges from any channel or an external source, high/low/don't-care patterns from all channels, logical combinations and sequences of patterns, and patterns that repeat for a specified number of times or a specified interval.

The analyzer's cursor- and automatic-measurement modes should be familiar to

(continued to pg 18)

scope users. Another feature helps you keep track of the meanings of the many displayed signals; a labeling facility lets you select signal names from a menu of standard names augmented by the 85 names you defined most recently. The unit groups its 8-pf-capacitance inputs into a pair of eight-channel pods.—by Dan Strassberg

Hewlett-Packard Co, Santa Clara, CA, (800) 452-4844. **Circle No. 462**



Although HP's 54620A looks like a scope, it is a low-cost, 16-channel logic-timing analyzer with 2-nsec resolution and controls that users can learn rapidly.

Philips ties with IBM and buys HDL Systems

Philips Electronics and IBM are setting up joint manufacturing to increase Philips' capacity for 0.8-µm wafers and to provide access to IBM's DRAM technology. The venture will be based at IBM's plant in Boeblingen Hulb in Germany, which manufactures 4-Mbit DRAMs. The companies are planning for Philips to

(continued on pg 20)

Processor-core deal adds vital element to ASIC range

An exclusive licensing agreement between Alcatel Mietec (Belgium) and Nordic VLSI (Norway) adds an 8-bit µRISC processor core to other significant features of a new range of ASICs from Alcatel Mietec. Alcatel Mietec is one of Europe's leading suppliers of mixed-signal ASICs to automotive, industrial, and telecommunications markets. The new range—Intelligent Interfacing Technology (I^2T)—aims to consolidate that position, ahead of closest rivals Motorola and Texas Instruments.

I^2T ASICs use a 0.7-µm, 5V CMOS process for high-density digital circuitry, to which you can add various modules to increase functionality, particularly for interfacing applications. The additions include Nordic's MTC-8308 µRISC module, linear analog modules, high-voltage switching modules, and memory modules. I^2T ASICs maintain compatibility with Mietec's ASIC device libraries, and the modular-design approach offers flexibility to control cost by limiting mask count.

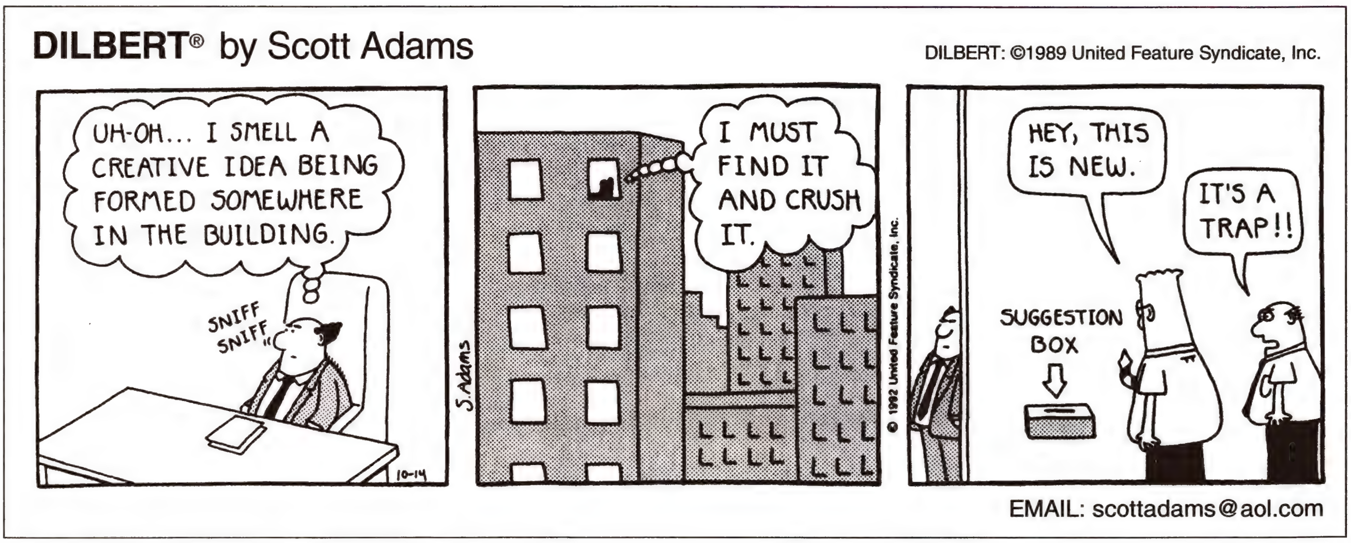
Nordic's MTC-8308 core is a 40-MHz 8-bit processor with up to 4 kbytes of ROM, 192 bytes of RAM, and 31 instructions. Mietec has integrated a set of design tools that support Nordic's core into its the "MADE" ASIC design system. The tools include a C compiler, a macro assembler, a VHDL model, a software simulator, and a hardware emulator.

I^2T ASICs include 12V CMOS and bipolar modules (including an 18V capability for programming) for linear-analog functions. The ASICs also include 100V n- and p-type DMOS modules for high-voltage switching functions. By mid-1995, the company will add a one-time-programmable, nonvolatile, 100-bit memory module for functions such as identification and calibration. Other future additions include up to 8 kbits of EEPROM, 64-kbit flash-memory modules, and 16-bit MTC-8316 and DSP MTC-8300 modules.

—by Brian Kerridge

Alcatel Mietec, Brussels, Belgium, 2 728 18 11. **Circle No. 463**

Nordic VLSI, Flatasen, Norway, 72 58 62 11. **Circle No. 464**



POWER FOR Communications

Vicor Corporation, the leader in the component power industry, understands the needs of the telecommunications power system designer.

Our DC-DC converters and converter-based "total solutions" are designed to provide maximum flexibility and quick time to market, with safety agency approvals (UL, CSA, TÜV, VDE, BABT and UL94V0), a fixed form factor that enhances future upgrades and user definable outputs. Standard models are battery plant compatible, with 24V and 48V input versions for cellular and central switching applications. Our automated manufacturing facilities are ISO and BABT approved, and our converters have been field-proven through an installed base of over 3 million units, with demonstrated MTBFs as high as 20,000,000 hours.

In short, the inherent "plug and play" flexibility of our high density DC-DC converters gives you the power for communications...whenever and wherever required. And all Vicor products are supported by a global applications staff that's just a phone call away.

For more information on our complete line of component power products and total power solutions, give us a call at (800) 735-6200.

Component Solutions For Your Power System

Vicor Corporation 23 Frontage Road • Andover, MA. 01810 USA • Tel: (508) 470-2900 • Fax: (508) 475-6715
Vicor Europe Carl-von-Linde Strasse 15 D-85748 Garching-Hochbruck, Germany • Tel: +49-89-329-2763 • Fax: +49-89-329-2767
Vicor Asia-Pacific 10F, No. 7, Ho Ping E. Road, Sec. 3, Taipei, Taiwan • Tel: 886-2-708-8020 • Fax: 886-2-755-5578

VICOR

license IBM's 16-Mbit technology for embedded DRAM applications in consumer and multimedia products.

Philips Semiconductors has also acquired 100% of HDL Systems (Sunnyvale, CA), a manufacturer of 32-bit μPs. Philips needs a 32-bit architecture to offer users a performance path from the 8-bit embedded 80C51 via the recently announced 16-bit 80C51 extension.

HDL's MR300 processor core—designed under Mips R3000 RISC license— provides Philips with an easily extensible architecture for the embedded-microcontroller market. The MR300 uses zero power when the clock stops; this static design is critical to Philips' many battery-powered applications.—by Brian Kerridge

IBM Europe, Germany, (7117) 853407. **Circle No. 465**

Philips Semiconductors, Eindhoven, The Netherlands, (40) 722091. **Circle No. 466**

Book helps you manage system power

As portable computers evolve, users are witnessing the trends toward higher performance and longer battery life. Until now, battery life, alias power management, has been an art rather than a science. Even though the Advanced Power Management specification (from Microsoft, Intel, and Phoenix) defines a standardized interface between compliant applications and the system BIOS, many variables exist within each system's BIOS. For that reason, no one until now has attempted to write a book on the *science* of power management.

Now, James Bunnell has tackled the subject in his book, *Power Management That Works*, which formalizes and makes practical power-management concepts. Between the book's covers, Bunnell explains how to determine when a system is idle, the most challenging aspect of the subject. Toward that end, he begins by breaking down the subsystems into simple and complex devices and discusses the mechanisms for monitoring them. The book also covers the user interface, suspending the computer, hardware and software interactions, and current and future power-management models. Bunnell doesn't believe in giving end users power-management options in their notebooks. (I agree: Figuring out how to use these options practically requires a three-day training course.)

The book is easy to read and comprehend and provides an extensive—perhaps excessive—use of analogies. Whether you're a system designer or just someone interested in the subject of PC power management, this book, at $24.95, provides a lot of value.—by Markus Levy

Annabooks, San Diego, CA, (800) 462-1042. **Circle No. 469**

UK companies expand wafer-fab facilities

GEC Plessey Semiconductors (GPS), the only UK-owned CMOS manufacturer, will invest $150 million in its Roborough, UK, CMOS ASIC plant. The investment will enable the company to move from 6- to 8-in. wafers and to quadruple output by 1996. GPS will devote around 10% of the investment to advanced process development, including 0.25-μm geometry. The new facility will incorporate a clean-room-within-clean-room environment that reduces time to market, enhances wafer protection, and improves yield. The investment announcement scotches rumors that GPS might be sold to Rockwell.

In a second UK fab investment, NEC has selected Scotland in favor of California for an $800 million investment in a new facility. The plant will output 0.35-μm-process, 16- and 64-Mbit DRAMs and advanced ASICs at 20,000 8-in. wafers/month beginning in October 1996. The company chose to develop its NEC Semiconductors (UK) Ltd base due to high European demand and because the plant is NEC's most productive.—by Brian Kerridge

GEC Plessey Semiconductors, Swindon, UK, (793) 518128. Circle No. 467

NEC Semiconductors (UK) Ltd, London, UK, (71) 353 4383. Circle No. 468

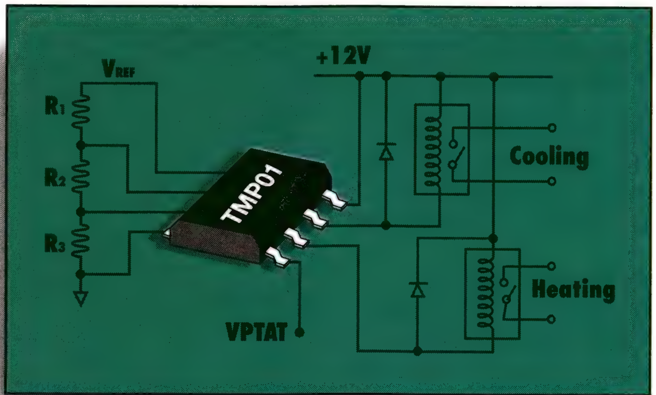
Regulator lowers maximum dropout to 35 mV

According to Texas Instruments, low-dropout regulators (LDOs) have been a product waiting for a technology. The company now claims to have the technology, a linear BiCMOS process, and has introduced a family of LDOs, which, among other features, reduces dropout voltage by an order of magnitude compared with previous LDOs. At load currents of 100 mA, the *maximum* dropout voltages range from 35 mV (for the 4.85 and 5V output devices) to 60 mV (for the 3.3V output device). In addition, the regulators feature a typical quiescent current of 285 μA (for inputs around 5V) that's independent of the load. Maximum sleep-state current is 1 μA.

Most of the advantages of the TPS71xxQ family stem from using a PMOS device instead of the more traditional pnp pass transistor. Low dropout voltage results from the PMOS device's behavior as a low-value resistor. Regulator quiescent current is independent of the load because, unlike with pnp types whose base,

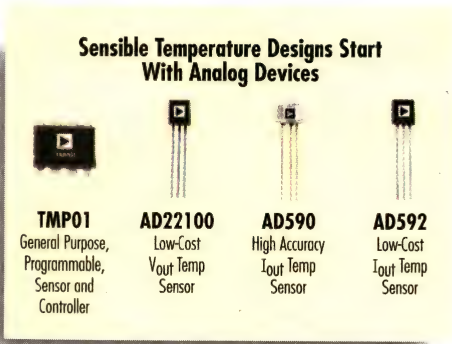
(continued on pg 22)

Single-Chip Sensor/Thermostat Simplifies Temperature Monitoring And Control.



Pre-Calibrated.
Accurate.
Affordable.

Introducing the TMP01, an integrated single-chip temperature sensor and controller that provides significant advantages over electromechanical devices for general purpose temperature monitoring applications.



The TMP01 is exceptionally easy to use. Upper and lower temperature limits and hysteresis are set by three external resistors, with the exact set point values instantly calculated with accompanying design software. The sensor generates a voltage output proportional to temperature (VPTAT), with a sensitivity of 5mV/K over the temperature range.

Other TMP01 advantages include low power, single supply operation; 20mA open collector outputs to drive relays or to provide TTL/CMOS logic; over one month of continuous operation from a 9V battery; factory calibration to reduce manufacturing time and costs; and a variety of affordable plastic packaging options, starting at $1.95.*

For more information on TMP01, contact your local Analog Devices sales office or representative listed below.

ANALOG DEVICES

Analog. Digital. Solutions.

Analog Devices Europe: Austria (222) 88 55 04-0, Belgium (3) 2482619, Denmark (42) 84 58 00, France (1) 46744500, Germany 089/57005-0, 030/391 90 35, 04181/80 51, 0221/68 60 06, 0711/88 11 33, Israel (9) 911 415, Italy (2) 665 00 120, (11) 24 87 789, (6) 86 200 306, Netherlands (1620) 815 00, Sweden (8) 282 740, Switzerland (1) 820 01 02, (21) 803 25 50, United Kingdom 0932 266000

* USD 1,000s, recommended resale, FOB U.S.A.

CIRCLE NO. 4

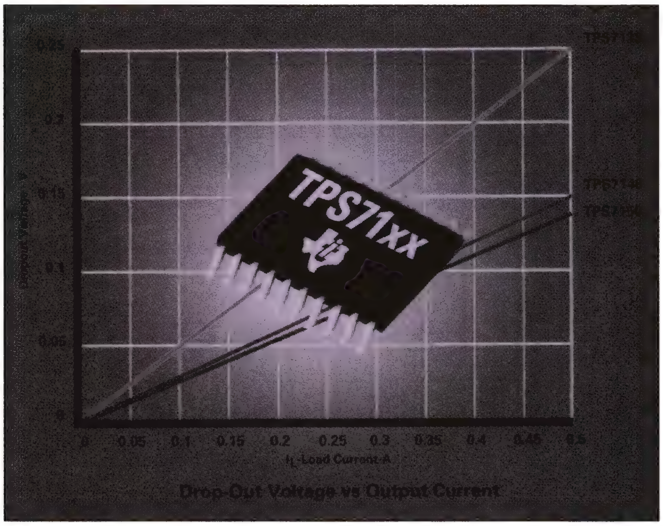
output, and supply current are interdependent, a PMOS element is a voltage-driven device. Thus, operating currents are low and stable over the full load range, and specifications reflect actual loaded performance. Also unlike pnp-based LDOs, these regulators' supply current stays low even in dropout, whereas bipolar LDOs' supply current can increase and potentially cause start-up failures.

TI engineers concentrated not just on reducing dropout voltage and quiescent current but also on competitive noise and regulation specifications. These regulators have a 1% initial output tolerance and a maximum 2% tolerance over full line, load, and temperature ranges. Although you might not expect good noise performance from a low-power CMOS device, these regulators also compete with bipolar devices on this point. Typical output-noise spectral density at a 120-Hz frequency is 4 $\mu V/\sqrt{Hz}$ for the 5V device.

In addition to the 5V (TPS7150), 4.85V (TPS7148), and 3.3V (TPS7133) versions, the family includes a 1.2 to 9.75V (TPS7101) adjustable regulator. Designed for 5V cellular systems, the TPS7148's 4.85V, ±2% output allows it to operate to the limit of 5V systems specified to ±5% tolerance, extending the operating life of the battery pack. Other features of these LDOs include a low-output-voltage indicator, sleep-mode shutdown, and operation with one small, external 4.7-µF tantalum capacitor. Package options include DIP, SOIC, and TSSOP. Prices range from $1.45 to $1.65 (1000).—by Anne Watson Swager

Texas Instruments, Literature Response Center, Denver, CO, (800) 477-8924, ext 3477.

Circle No. 470



The first products using Texas Instruments' linear BiCMOS process, the TPS71xx family of low-dropout regulators feature dropout voltages an order of magnitude lower than that of their purely bipolar counterparts.

Windows interprocess link runs 1000 times as fast as DDE

A new interprocess link proves a bonanza for developers of real-time applications that run under Windows. LT-Speedway not only offers performance 1000 times as fast as Windows' dynamic data-exchange (DDE) facility, but also lets you download the code free via the Internet. The code for the link is an Internet Anonymous FTP (file-transfer protocol) archive, which means that it's in the public domain. You need to "ftp" two files, LTSPEEDW.ZIP and LTPSPEEDW.TAR.Z, from the /vendor/labtech directory at the ftp.uu.net site. Or get the same files from the Labtech forum library on CompuServe (type GO LABTECH).

To achieve its performance, LT-Speedway uses shared memory, thus avoiding Windows' single-threaded message queue. On a 90-MHz Pentium-based PC, the link transfers messages every 38 µsec. There is no limit to how much data a message can contain. The object-oriented software is not restricted to use with Windows applications; the link also runs under Harris Corp's Unix.

The software functions with object linking and embedding (OLE) V2.0 using OLE automation features. For Windows developers who require in-depth support, Labtech offers a $1995 development kit that includes documentation, sample programs, and periodic code updates.—by Dan Strassberg

Labtech, Wilmington, MA, (508) 657-5400.

Circle No. 471

Test conference stresses high-level DFT, BIST, IDDQ

At this year's Silver Anniversay Edition of the International Test Conference, which took place in Washington, DC, from Oct 2 through 5, several trends appeared: The first is the emergence of tools for introducing test-related constraints into designs at the behavioral-modeling stage. Among companies offering such tools are LogicVision and Mentor. If these tools succeed, they will significantly reduce development time by eliminating much of the iteration IC design now requires.

The second trend is the growing recognition of the importance of built-in self-test (BIST) on ICs and the refinement of tools for synthesizing BIST structures—not just for RAM but for random logic. Examples of such tools come from AT&T Design Automation and IBM/Altium.

The third noteworthy trend is the increased level of discussion of IDDQ testing and the greatly increased number of commercial tools that support the technique. IDDQ detects faults in CMOS ICs

(continued on pg 24)

by monitoring the supply currents, I_{DDQ} and I_{SSQ}. Many foundries have used IDDQ for years as an adjunct to more widely known methods, but now its power and shortcomings are emerging. Among the companies showing IDDQ products were AT&T Design Automation, Crosscheck, Cadence, Sunrise, Synopsys, and Teradyne.

Another trend evident at ITC focused on board test—now a mature industry. Although the number of systems that board-tester vendors ship continues to rise, system prices are declining even faster, so board-tester revenues are declining. Over the years, the emphasis in board test has gone from functional to in-circuit test and then to a combination of in-circuit and functional test. As surface-mount has become dominant in pc-board-assembly technology, the tester focus has shifted toward combining manufacturing-defects analysis (a simple form of in-circuit testing) and low-cost functional testing. Both Hewlett-Packard and Teradyne announced testers that add functional test to low-cost in-circuit test systems, and GenRad announced several low-cost application-specific functional test systems for boards and assemblies.

An area related to board test is boundary scan. LSI Logic reported that approximately 60% of new ASICs contain structures that enable board testing in accordance with the IEEE-1149.1 boundary-scan standard. Companies introducing new boundary-scan test products at ITC included Corelis and its European partner, JTAG Technologies, and Alpine Image Systems. These companies' products are low-cost test systems and test-system components. At the IC level, both National Semiconductor and Texas Instruments announced parts.

—by Dan Strassberg

Alpine Image Systems, Los Altos, CA, (415) 941-3247. **Circle No. 472**

Altium, an IBM Company, San Jose, CA, (408) 534-4100. **Circle No. 473**

AT&T Design Automation, Murray Hill, NJ, (908) 582-4083. **Circle No. 474**

Cadence Design Systems Inc, Beaverton, OR, (503) 626-7117. **Circle No. 475**

Corelis Inc, Cerritos, CA, (310) 926-6727. **Circle No. 476**

Crosscheck Technology Inc, San Jose, CA, (408) 432-9200. **Circle No. 477**

GenRad Inc, Concord, MA, (508) 369-4400. **Circle No. 478**

Hewlett-Packard Co, Santa Clara, CA, (800) 452-4844. **Circle No. 479**

JTAG Technologies BV, Eindhoven, the Netherlands, 31-40-782-584. **Circle No. 480**

LogicVision, San Jose, CA, (408) 453-0146. **Circle No. 481**

LSI Logic Corp, Milpitas, CA, (408) 433-8000. **Circle No. 482**

Mentor Graphics Corp, Wilsonville, OR, (503) 685-7000. **Circle No. 483**

National Semiconductor Corp, Santa Clara, CA, (800) 272-9959. **Circle No. 484**

Sunrise Test Systems Inc, Santa Clara, CA, (408) 980-7600. **Circle No. 485**

Synopsys Inc, Mountain View CA, (415) 962-5000. **Circle No. 486**

Teradyne Inc, Agoura Hills, (818) 991-2900. **Circle No. 487**

Teradyne, Boston, MA, (617) 422-3567. **Circle No. 488**

Texas Instruments Inc, Dallas, TX, (214) 575-6396. **Circle No. 489**

For information from all of the above companies circle just one number. **Circle No. 490**

Floppy-disk controller conforms to ISA Plug-and-Play standard

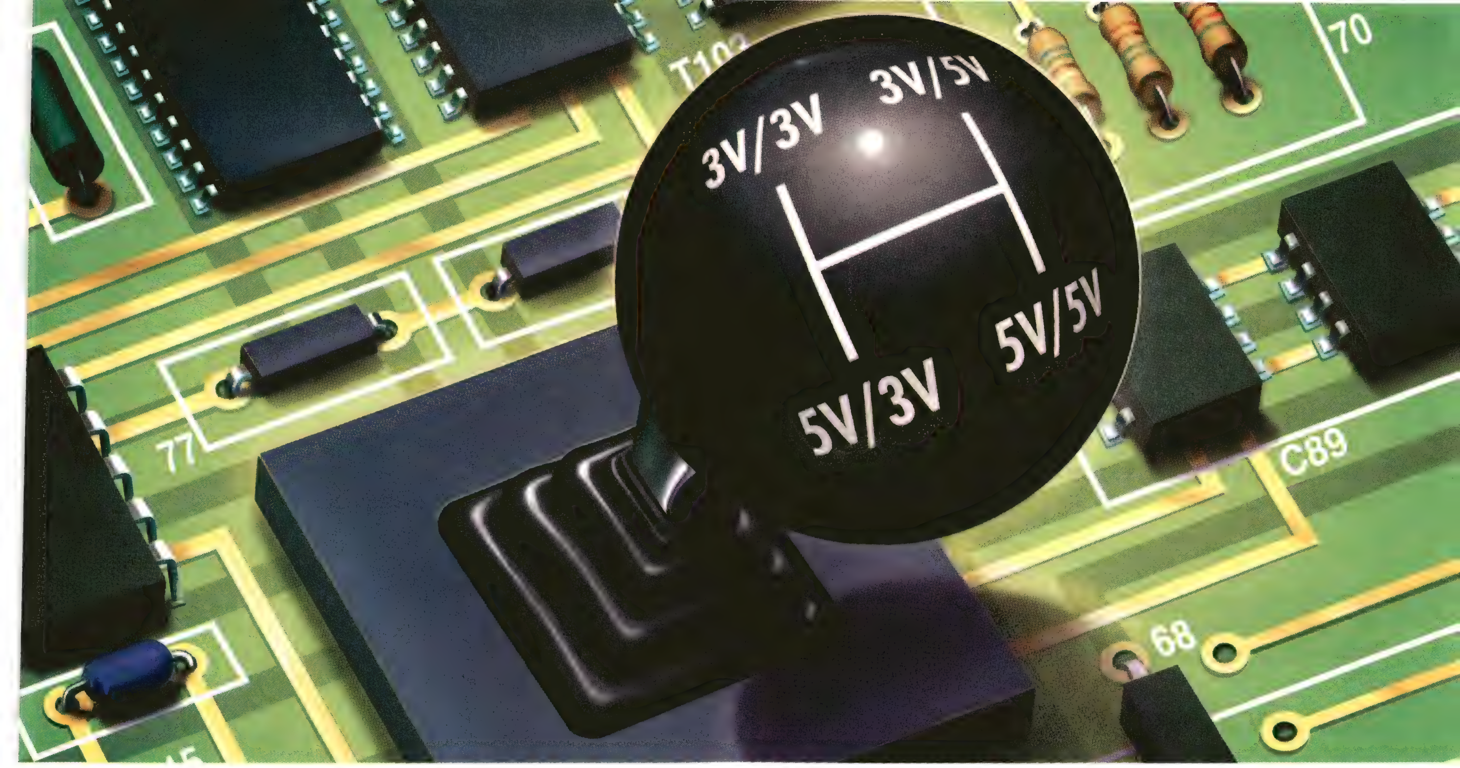
Standard Microsystems' FDC37C667 parallel-port Super I/O floppy-disk controller is the first such device to comply with the ISA Plug-and-Play standard (Version 1.0a). It also operates in systems running Microsoft Corp's soon-to-be-released Windows 95, known as "Chicago." Internal configuration registers allow you to program each of eight logical devices in the Super I/O chip. The eight logical devices are a floppy-disk controller; two IDE interfaces supporting four drives, including a CD-ROM; a game port; a general-purpose address decoder; a multimode parallel port; and two NS16C550-compatible UARTs with 16-byte FIFO buffers for serial communications.

The multimode parallel port can operate in standard and enhanced high-speed modes and includes a ChiProtect feature that prevents damage to the chip during printer power-up. Operating in standard mode, the parallel port is compatible with ISA bus and PS/2 computer architectures. In high-speed mode, the port is compatible with the enhanced parallel port (EPP 1.7 and EPP 1.9) standards and the extended-capabilities port (ECP) standard.

The chip comes in a 160-pin QFP and is configurable for motherboard or expansion-card applications. In motherboard applications, Plug-and-Play software allows the system to allocate resources using BIOS instructions. The chip has 15 selectable interrupt-request lines, three selectable 8-bit DMA channels, and three selectable 16-bit DMA channels.

An optional EEPROM interface allows nonvolatile storage of system configurations for use on reboot. In

(continued on pg 26)



POWER SHIFTER.

H4CPlus™ Series Gate Arrays let you select the voltage scheme that meets your power and performance goals.

Thanks to continually shrinking gate length and other process improvements, today's ASIC chips are able to run at lower voltages without giving up much performance—3V vs. 5V. However, the transition to complete 3V systems must wait until standards catch up and components are produced in economical volumes. So, it's become a mixed-voltage world in which designers are incorporating into most new designs both 3V and 5V components.

Single-chip solution to mixed-voltage challenges

Motorola's H4CPlus CMOS gate arrays are designed to interface between 3.3V and 5V, minimize power dissipation, and support high frequency communications, while cutting system cost. *Now* designers can choose the voltage scheme that provides the performance required at the lowest power.

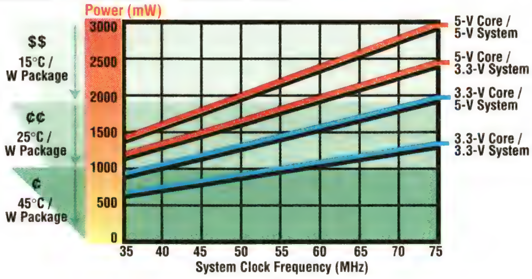
H4CPlus allows optimization of either the array core or I/O power—or both. Core may be 3.3V or 5V, I/O buffers 3.3V only, 5V only, or mixed.

H4CPlus Features

- 0.65 micron effective gate length.
- Triple layer metal.
- 21K to 296K available gates.
- Ball-Grid Array and QFP packaging.
- Chip-to-chip interface speeds exceeding 200MHz.
- Power savings up to 60% by running core and most of I/O at 3.3V, while retaining performance nearly equal to 5V designs.

Want to shift to an easier life in the mixed-voltage world? Send the coupon below, or write Motorola Ltd., European Literature Centre, 88 Tanners Drive Blakelands, Milton Keynes MK14-5BP, United Kingdom. Ask for data sheet H4CP/D.

Power Choices
Pick lower voltage supplies to reduce package cost.

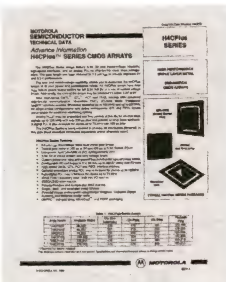


A Typical Application

MOTOROLA

Motorola and Ⓜ are registered trademarks of Motorola, Inc.

Motorola Ltd., European Literature Centre, 88 Tanners Drive, Blakelands, Milton Keynes MK14-5BP, United Kingdom



Please send me H4CP/D data sheet. 647EDN111094

Name

Title

Company

Address

City

Country

adapter-card applications, an EEPROM stores the Plug-and-Play serial identifier, resource data, and a proprietary boot-configuration word.

The 0.8-μm CMOS chip uses the company's SuperCell technology and incorporates an advanced digital data separator and CMOS 765B floppy-disk-controller core. The core supports data rates as fast as 1 Mbps for vertically recording floppy-disk and high-speed tape drives. The chip sells for $10 (1000), and production orders ship 12 weeks ARO.—by John Gallant

Standard Microsystems Corp, Hauppauge, NY, (516) 435-6000. **Circle No. 491**

BOOK REVIEW

Survival in the EE shark tank

John A Hoschette's 200-pg *Career Advancement and Survival for Engineers* proffers a variety of career-networking strategies and creative routes for improving your marketability as an EE.

Hoschette suggests proactive techniques for surviving corporate takeovers and downsizing, establishing and developing relationships with mentors, and exploiting the benefits of your company's continuing-education system. Hoschette, an electro-optics expert with 18 years of field-test, design-and-development, and management experience, derives much of the material in this book from a career-development course he created with Honeywell in Minneapolis.

The text outlines 14 areas of career education and planning. "Are you in control of your career?" "Determining the formal and informal criteria by which you are judged," "What are the leading reasons engineers fail?" and "Getting on the fast track for advancement" are a sampling of chapter headings.

Hoschette's *Career Advancement and Survival for Engineers* costs $39.95 (hardcover) and $15.95 (paperback).

—by Jim Leonard

John Wiley & Sons Inc, New York, NY, (800) 225-5945; (212) 850-6418. **Circle No. 492**

Design kit speeds PCI-based ASIC designs

An electronic-design-automation tool kit for Synopsys' DesignWare product line makes it easier for designers to add a Peripheral Component Interconnect (PCI) interface to an ASIC. The kit includes a set of customizable high-level macros, a bus model for simulation, and a test suite to verify a design's compliance with the specification. The technology-independent macros include an interface, master and slave state machines, slave address recognizers and mappers, and master and slave data paths. The macros are fully synthesizable and allow you to use only those blocks you need for your implementation. A one-year license costs $40,000. The macro set, bus model, and test suite individually cost $30,000, $23,000, and $23,000, respectively.—by Richard A Quinnell

Synopsys Inc**, Mountain View, CA, (415) 637-8212.* ***Circle No. 493

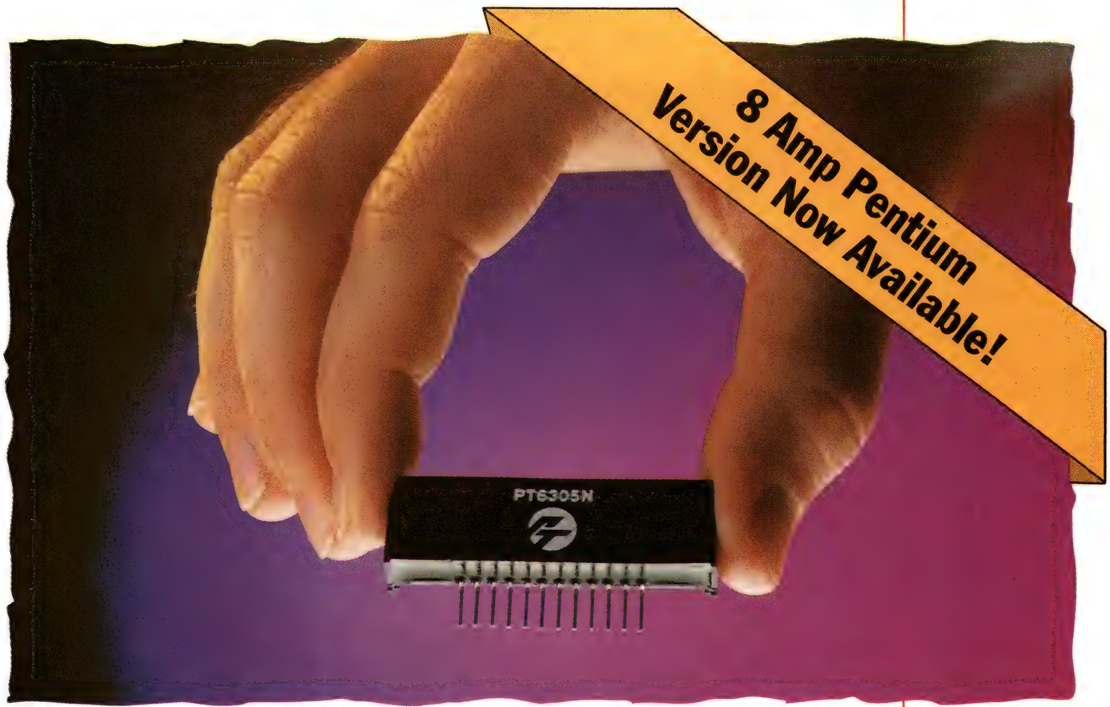
DC/DC converter meets Type I PCMCIA minimum thickness

In a 20-pin, 1.1-mm-thick TSSOP package, Linear Technology's LT1106 meets the maximum 3.3-mm thickness requirements for PCMCIA Type I flash-memory cards. With its 500-kHz switching frequency, the IC also allows the use of equally thin 10-μH inductors and thin, low-value output capacitors. The flash-memory power-supply IC senses the available inputs from a PCMCIA connector and, if no 12V supply is available, generates 12V from either a 3.3 or 5V V_{CC} supply. To power 5V flash memories, the IC can also generate a 5V V_{PP} output from V_{CC}. Thus, you can use the device to supply a 5 and 12V flash memories, guaranteeing a programming voltage even only a 3.3V supply is available at the PCMCIA connector. Other features include V_{PP} input-voltage-detection comparators, p-channel MOSFET control for V_{PP}-to-flash output switching, and shutdown to 9 μA. The LT1106 ($5.63) is available on tape-and-reel (2500-piece minimum order).

—by Anne Watson Swager

Linear Technology Corp, Milpitas, CA, (408) 432-1900. Circle No. 494

SINGLE-DEVICE 5V TO 3.3V POWER



...THAT PLUGS RIGHT IN.

JUST
PLUG
IT IN

Now, from the innovator in integrated switching regulators, comes a new series of high-performance 5V to 3.3V, 3A and 8A single in-line products. The new Power Trends PT63/65 series lets you easily solve the problem of integrating 3.3V logic into existing 5V systems, ***without redesigning your power supply.***

And, the PT63/65 family conserves board space with a profile as low as .36" x 2.00" x .60" (H). Vertical, horizontal and surface mount versions are available.

The PT63/65 family features operating frequencies of 550KHz or more, 85% efficiency, over-temperature and short circuit protection. The PT63/65 family supports outputs of 2.1, 1.8, 1.5 and 1.2 volts.

If you're ready for a space-saving on-board power converter that you can plug right in, ***call Power Trends for a sample today!*** **1-800-531-5782.**

POWER TRENDS®

1101 North Raddant Road, Batavia, IL 60510 • (708) 406-0900 • Fax (708) 406-0901

CIRCLE NO. 66

PORTABLE

DESIGN SOLUTIONS

Reduce Power Consumption.

ELECTRONIC DEVICE GROUP

Increase Performance.

Low voltage operation and energy savings are the two most critical factors driving next-generation portable and "green" electronic product designs. That's where Mitsubishi's extensive line of low-voltage ICs and high-efficiency RF devices can help you reduce power consumption and increase performance.

Mitsubishi 3V ICs can help reduce system power by as much as 50%, significantly extending the battery life of portables. Plus, low-power ICs enable increased system performance while still drawing less power than at 5V. Mitsubishi's extended temperature range GaAs MMICs offer 60% efficiency helping cut power requirements and increase durability in wireless portable products.

PRODUCT	DENSITY	V_{CC}	I_{CC} (Typ.)	I_{sb} (Typ.)	FEATURES/BENEFITS
Synch. Cache DRAMs	16M, 4M (x4, x16)	3.3V	170mA	5mA	LVTTL Compatible; Burst & Power Down Modes; Ext. Ref.
Synchronous DRAMs	16M (x4, x8)	3.3V	180mA	2.5mA	Burst & Power Down Modes
EDO DRAMs	16M, 4M	3.3V	120µA	1mA	Hyper-page Mode; Ext. Ref.; Low SER
DRAMs	16M/4M	3.3V	75mA/60mA	500µA/120µA	Reduced Switching Noise; Low SER; Self Refresh
Flash ICs	1M (x8)	5.0V(V_{pp}=12.0V)	15mA	50µA	Bulk Array; Power Up/Down Data Protection; Ind. Temp.; Volume Capacity
Flash ICs	1M (x16)	5.0V (V_{pp}=12.0V)	25mA	50µA	Wordwide Architecture; Socket Compatible with x16 EPROMs/OTP ROMs
Flash ICs	4M (x8, x16)*	5.0V (V_{pp}=12.0V)	35mA	50µA	32 Blocks (16KB/8K word); Optimized for Data Storage; Auto Program/Erase
Flash ICs	16M (x8)	3.3V (V_{pp}=12.0V)	15mA	0.5µA	Easy Upgrade from Ind. Std. 8Mb Flash Designs; Auto Program/Erase; Deep Power Down Mode; 32 Blocks (64KB ea.)
IC Cards	256KB-40MB	3.3/5.0V	110mA	150µA	Ext. Configurable; 1.4µA Data Ret.; Type I PCMCIA/3.3mm
I/O Cards (10 Base T)	–	5.0V	250mA	–	LAN; Ext. Configurable; Type II PCMCIA/5.0m
I/O Cards (24/96)	–	5.0V	150mA	–	Fax/Modem; Ext. Configurable; Type II PCMCIA/ 5.0mm
Low Power Slow SRAMs	4M (x8)	3.3V	25mA	.4µA	Low Standby Current; Ext. Temp.; TFT Cell
Low Power Slow SRAMs	1M (x8, x16)	3.3V	8mA/15mA	.05µA/1µA	Low Standby Current; Ext. Temp.; TFT Cell
Fast SRAMs	256KB (x8)	3.3V	100mA	100µA	High Performance; Low Power; Ext. Temp.
Fast SRAMs	1M (x1, x4)*	3.3V	100mA	100µA	High Performance; Low Power; Ext. Temp.
Fast SRAMs	1M (x8)	3.3V	100mA	100µA	High Performance; Low Power; Ext. Temp.

*User Selectable

PRODUCT	V_{CC}	I_{CC}	FEATURES/BENEFITS
Baseband ICs	3.3V	16mA (max.)	On-board Scrambler, Compander, Modem
Battery Recharger ICs	3.0/5.0V	18mA/15mA (typ.)	On-chip D/A Converter; Maximizes Battery Life
D/A Converters	3.0V	3.5mA (max.)	8-bit; 12- and 36-channels
DC-DC Converter	2.5V	1.3mA (typ.)	For Backlight Control; Output Short Protection; High Speed Switching (300KHz)
LCD Controller Driver	5.0V	-	Low Power, Dot Matrix LCD Control
Dual PLLs	1.8V	7.5mA (typ.)	410MHz; Various Power Save Modes
Reset ICs	2.5V	1mA (typ.)	Reduces MCU Power Diss; Low Power 2-output; Memory Backup Avail.
GaAs MMICs	3.4V	250mA	800MHz-1.9GHz Band Operation; 60% eff.; Leadless Pkgs.
0.8µm Gate Arrays/ECAs	3.0V*	–	Very Low Power Diss.; 0.8µW/MHz/gate @ 3.0V; up to 400K Gates
8-Bit LCD MCUs	2.7V	1.6mA (typ.)	Up to 48KB ROM On-chip, LCD Controller
8-Bit Keyboard MCU	2.7V	1.6mA (typ.)	Keyboard Controller, Host Interface
8-Bit MCUs with Custom Logic Functions	2.7V	1.6mA (typ.)	3.0V up to 20MHz clock; User-defined Functions
8-Bit Magicbus™ MCU	2.7V	1.6mA (typ.)	Up to 32KB ROM
16-Bit High Performance MCUs	2.7V	4mA (typ.)	Up to 60KB ROM/2KB RAM or ROM-less; High On-chip Integration

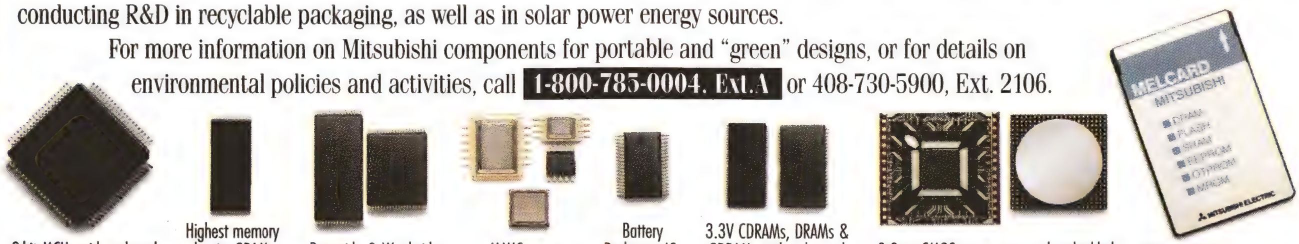
*Fully Characterized for 3.0V

For "green" PCs, monitors and printers, Mitsubishi 3V ICs help designers meet the U.S. Environmental Protection Agency's (EPA) Energy Star™ Program requirements to reduce standby system energy consumption to ≤ 30W, conserve energy, extend equipment life and reduce environmental pollution.

In addition to creating enabling components for portable and "green" end-product designs, Mitsubishi Electric Corporation is committed to "sustainable development." To this end, the company has eliminated CFCs, including 1,1,1-trichloroethane solvent and carbon tetrachloride, in manufacturing processes at all its semiconductor production facilities. The company is committed to reducing industrial wastes by 30% in 1995, cutting energy consumed in semiconductor production processes by 25% by the year 2000, and is conducting R&D in recyclable packaging, as well as in solar power energy sources.

Mitsubishi Electric's Symbol of Commitment to Developing Solutions for Semiconductor Environmental Issues.

For more information on Mitsubishi components for portable and "green" designs, or for details on environmental policies and activities, call **1-800-785-0004, Ext.A** or 408-730-5900, Ext. 2106.



8-bit MCUs with on-board dot matrix LCD controller

Highest memory density SRAMs with the lowest standby current

Bytewide & Wordwide 1M, 4M & 16M Flash Memories

MMICs up to 60% efficiency

Battery Recharger ICs maximize battery life

3.3V CDRAMs, DRAMs & SDRAMs with enhanced power management for "green" projects

0.8µm CMOS gate arrays and embedded cell arrays, up to 400,000 gates

PCMCIA/JEDEC standard and custom IC cards

CIRCLE NO. 154

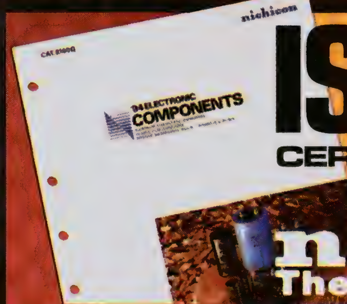
MITSUBISHI

Everyone wants their surface mount capacitor supplier to have ISO 9000 certification. That's why we've certified all of our manufacturing facilities. Not just one or two.

And nobody gives you a wider or more reliable choice of surface mount aluminum electrolytic and tantalum chip capacitors than Nichicon.

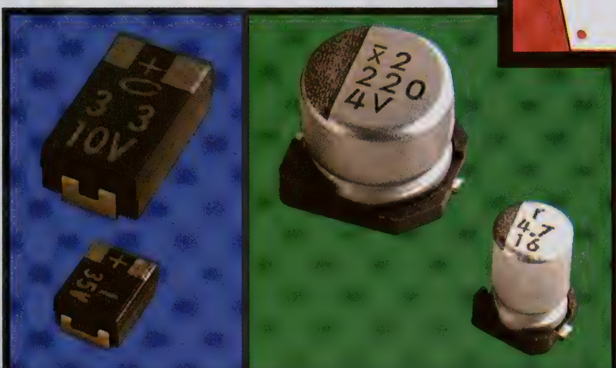
Fifteen series, designed to help you cut costs and speed assembly time. Each designed to help you match the operating performance and delivery dates you want to your product and facility needs.

THE WORLD CLASS ALUMINUM AND TANTALUM CHIP CAPACITORS.



ISO-9000
CERTIFIED EVERYWHERE.

nichicon®
The capacitor choice.



Talk to your Nichicon representative or distributor the next time you need surface mount capacitors. Or, call us at 708/843-7500, fax: 708/843-2798.

Reader notes correct source

While reading "Canny choices condense CPLD and FPGA design cycles" by Sung C Hu (*EDN*, August 4, 1994, pg 91), I found a mistake in the attribution of the quote "There are three kinds of lies: lies, damned lies, and statistics." Its origin actually lies with British Prime Minister Benjamin Disraeli, not Mark Twain.

Tom Nath, Senior Engineer
Thomson Consumer Electronics
Indianapolis, IN

Be wary of VHDL bandwagon

Although I enjoyed reading "VHDL emerges as a commercial design tool" by Karen Bartleson (*EDN*, August 18, 1994, pg 84) and share her enthusiasm for hardware-description languages, I strongly advise design and CAD engineers to consider Verilog HDL before blindly rushing to adopt VHDL. Verilog's syntactical kinship to C permits designers to learn it quickly and to write terse, readable, accurate code efficiently and cost-effectively. The Verilog equivalent of Bartleson's 16-bit VHDL counter model would be half as long and far more reader-friendly.

Before investing money and time to learn VHDL, the C-literate design engineer should try a free taste of Verilog by downloading the student version of the VeriWell/386 simulator from Wellspring Solutions (Sutton, MA).

John A Eldon
Principal Systems Engineer
Raytheon Semiconductor
San Diego, CA

Defense conversion troubling in real-world economy

I'm delighted to see *EDN* tackling the issue of defense conversion (Project Plowshare: Putting military technology to other uses, *EDN*, August 18, 1994). And it's high time—after five plus years of layoffs. I think, however, you miss an opportunity to address the concerns of your readers who have spent their entire careers in defense contracting.

I'd like to know how many of the EEs who worked on NAVSTAR, for example, are now employed at GPS-based companies. And it might be useful to look at commercial companies' abiding prejudice against job applicants with experience on DoD projects. Even in industries such as medical electronics, where ruggedizing and high reliability are important, most managers see no crossover of skills.

Retraining efforts thus far (like the attempt to turn a handful of Southern California EEs into environmental engineers) have been feeble at best. This issue needs to be addressed before the industry loses more mature engineering talent.

Kate Colborn, Editor
Diversity/Careers in Engineering
Center Harbor, NH

Add another vendor

The following supplier of design-for-test tools was omitted from the list of vendors on pg 28 in "ASIC Test: It's a new ball game" (*EDN*, September 29, 1994):

LogicVision
San Jose, CA
(408) 453-0146
Circle No. 366

Subtleties and suggestions for power distribution

I recently read "Distributed power takes center stage" (*EDN Asia*, August 1994); it is a good article that covers a lot of technical issues on distributed power. (*Ed note: This article appeared in EDN Asia and EDN concurrently; see "Distributed power: Where the power meets the load," April 28, 1994, pg 54.*)

However, I have found that the section "Constant vs variable frequency," which compares the relative merits of quasiresonant- and PWM-conversion techniques, has several points that were unfavorable toward PWM techniques:
1. "According to Vicor, the efficiency of PWM converters is usually lower than that of similar-capacity resonant converters."
Efficiency of a power converter is a complicated performance indicator that depends on many circuit and operation parameters. To simplify the discussion, a PWM converter has lower

conduction losses but higher switching losses than a quasiresonant converter (QRC) at the same switching frequency. Since switching losses are proportional to switching frequency, the power losses in a PWM converter exceed QRC above a certain switching frequency (approximately 500 kHz in practice). On the other hand, the high conduction losses in QRCs make them less efficient than their PWM counterparts at lower switching frequencies. Thus, obtain the best efficiency by using a "low" switching frequency for a PWM converter and a "high" switching frequency for a QRC. The important job for the power-supply design engineer is to optimize a design at the chosen switching frequency. When the switching frequency is optimized, the PWM converter and QRC have similar efficiencies, which can be observed from the efficiency figure in the converter's data sheet. Therefore, the statement should read: "The efficiency of PWM and quasiresonant converters is similar if their designs are optimized."

2. "Vicor also notes that a PWM converter's efficiency drops rapidly with load."

Since the power dissipation in the power MOSFETs and rectifiers (and even the wires) of a power converter increase with increased current passing through, the power converter's power losses inevitably increase with increased output current—regardless of whether or not the converter is using PWM or QRC techniques. Again, such characteristics can be observed from the inverted-V shape of the efficiency-load curve of most power converters. Thus, the statement should read: "Most converters' efficiency drops with increased load."

3. "PWM converters'...output ripple increases with load."

A flyback-type converter has output-ripple increase with load current, no matter if it is PWM flyback or quasiresonant flyback. On the other hand, output ripple of forward or bridge-type converters is constant, independent of load current, no matter if it is a PWM forward/bridge or quasiresonant forward/bridge. Therefore, the statement should read: "Whether output ripple of power converters increases with load depends on converter topology rather than conversion technique."

PWM- and quasiresonant-conversion technologies have been around for 20 and 10 years, respectively. Neither technology outperforms the other in all aspects, which is why both technologies are still used in [designing] products. For the power-supply user (rather than designer), the best proof for the above claims is the converter's data-sheet specifications—or a simple measurement.

Kwok-wai Ma, Application Manager
Ericsson Components AB East Asia
Hong Kong, China

Sound off

Send your letters to Signals and Noise Editor, *EDN*, 275 Washington St, Newton, MA 02158. Or fax us at (617) 558-4470. *EDN* reserves the right to edit letters for clarity and length.

CEIBO Development Tools of Choice

Ceibo DS-186 In-Circuit Emulator

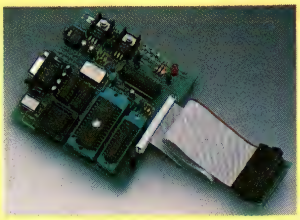
DS-186 real-time emulator supports microprocessors of the 80C186 family. The emulated devices are 80C186/8/XL/EA/EB/EC, V40/50, 8086/8 and more. The selection of a different microprocessor is made by replacing the microprocessor in the adapter or changing the adapter. The system features Full Speed Emulation up to 30MHz, 1 Mbytes of Zero Wait-State Mapped Memory, 8K Frames Dynamic Trace Buffer, 1M Hardware Breakpoints and 115KBaud RS-232C Communication Link. Breakpoints are qualified by instruction fetch, instruction execution, data contents, read/write from/to memory and I/O. The Trace display shows source, assembler and bus cycles. The system runs at the frequency of the crystal on the adapter or from the clock source supplied by the user hardware. The software supplied as standard is Paradigm Debug and Locate.

Ceibo DS-51 - Microprocessor Development System

Ceibo DS-51 is a real-time in-circuit emulator dedicated to the 8051 family of microcontrollers. It is serially linked to an IBM PC or compatible host and carries out a transparent emulation on the target microcontroller. DS-51 supports the new low-power and low-voltage 8051 microcontrollers and derivatives. The system can emulate the microcontrollers using either the built-in 5V power supply or any voltage applied to the target circuitry. This selection is done by means of software control. The permitted voltage range is from 1.5V to 6V or higher. DS-51 emulates almost every 8051 derivative in the complete voltage and frequency range specified by the microcontroller manufacturer. The minimum frequency is determined by the emulated chip characteristics, while maximum frequency is up to 40MHz. The software includes Source Level Debugger for PLM and C, Assembler Debugger, Performance Analyzer, On-line Assembler and Disassembler, Conditional Breakpoints and many other features. Standard systems are supplied with 128KBytes of Internal Memory, 64K Hardware Breakpoints, 32K Real-Time Trace Memory and personality probe supporting most of the 80C51 microcontrollers.

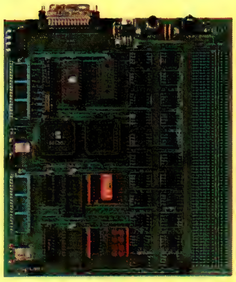
Development Tools

Ceibo offers a broad line of dedicated Development Tools for emulating different Microcontrollers and including all the necessary elements to design and debug your embedded system. Among these tools are DB-501, DS-750 and DS-752.



DB-51 Development Board

Ceibo/Philips DB-51 is a system design board dedicated to the 80C51 microcontrollers and derivatives. The software supplied with DB-51 includes Source Level Debugger for Assembler, PLM and C, Performance Analyzer, On-line Assembler and Disassembler, Software Trace, Conditional Breakpoints and many other features. DB-51 provides 32K of user code memory and has a special wire-wrap area for prototyping.



MP-51 - Programmer

Ceibo MP-51 is a high-quality Microcontroller, Flash Memory, EPROM and PLD Programmer dedicated to all the microcontrollers belonging to the 8051 family, 24 to 32-pin EPROMs, high-density PLDs and PSD devices. MP-51 allows to enable or disable the PLD or Microcontroller security capabilities and handles Lock Bits and Encryption Table available in several Microcontrollers. MP-51 loads different file formats: Intel Hex, Intel OMF, Binary, Motorola S-records, etc. Adapters are available for all the possible packages, such as DIP, LCC, PLCC, SO, and QFP.

A Complete Line of Development Boards, Programmers and In-Circuit Emulators

CEIBO

For more information, contact us today:
TEL: 1-800-833 4084

CEIBO USA
7 EDGESTONE COURT,
FLORISSANT, MO 63033
TEL: 314-830 4084
FAX: 314-830 4083

CEIBO DEUTSCHLAND
RHEINSTRASSE 32
D-64283 DARMSTADT
TEL: 06151-27505
FAX: 06151-28540

CEIBO ISRAEL
MERKAZIM BLDG., 5 MASKIT ST.
P.O.BOX 2106, HERZELIA 46120
TEL: 972-9-555 387
FAX: 972-9-553 297

CEIBO SPAIN
JOSUÉ LILLO 41
MADRID 28018
TEL: 91-477 8995
FAX: 91-477 9075

SWEDEN - TEL: 0589-19250, FAX: 0589-16153 • ITALY - TEL: 051-727252, FAX: 051-727515 • FRANCE - TEL: 061-855767, FAX: 061-851914 • OTHER COUNTRIES - FAX: 972-9-553 297

CIRCLE NO. 117

It's the results, stupid!

Environmental regulations often place roadblocks in the way of new technologies that can significantly improve the environment. The main reason is lawmakers' and regulators' insistence on drafting regulations that require (or pro-hibit) the use of particular technologies. The situation with Rayovac's reusable alkaline cells (see pg 62) is a case in point. Several types of rechargeable batteries should be recycled because they contain materials such as lead and cadmium that must not be allowed to leach into the aquifers that supply drinking water. So several states set up rules that required recycling of rechargeable batteries.

> When Congress enacts environmental laws, it should empower rule-making bodies to create standards based on input from industry experts.

Then along came Rayovac. After years of trying, it had developed a rechargeable *alkaline* battery. Lo and behold, Rayovac's reusable battery was free of the materials that pollute water supplies. Could Rayovac start selling its new batteries? Not without some hassles. You see, the regulations decreed that because the batteries were rechargeable, they had to be recycled. But recycling would have been uneconomical—as well as unnecessary. Carried to their logical conclusion, the regulations could have prevented the sale of batteries that are safer for the environment than other types, both rechargeable and nonrechargeable.

Situations like this occur time and again in environmental law. Another example is the mandate in California and elsewhere that a percentage of vehicles produce zero emissions. Faced with this requirement and a short time frame for implementing it, the transportation industry seized on all-electric vehicles as the answer. Electrical, electronic, and battery technology almost certainly will play increasingly important roles in automobiles, but many of us have doubts about purely electric vehicles.

If you recall how electric power is generated and stored, you realize that, except maybe when the power source is hydroelectric, "nonpolluting electric vehicle" is an oxymoron. (Even hydroelectric power is not sacrosanct; environmentalists are likely to torpedo a major hydroelectric project in Quebec, partly because it would destroy forests. Instead of mandating "zero-emission vehicles" by a certain date, why not set realistic goals for the pollutants cars generate? And include the pollution from generating propulsion energy outside of the vehicles.

Regulators seem unable to focus on the results they are trying to achieve. Few design engineers would tolerate a marketing manager's telling them which ICs to use in a new design. Selecting ICs is the designer's job. Similarly, the design community should draw the line when regulators try to dictate what technologies to use.

Things can also go sadly awry when lawmakers set performance goals. The automotive corporate-average fuel-economy (CAFE) standard is a case in point. CAFE doesn't specify technology; it specifies performance—how many miles per gallon a car manufacturer's fleet must deliver. CAFE has worked well. By encouraging rather than *requiring* the development of fuel injection and µP-based electronic ignitions, it has dramatically improved fleet mileage. But CAFE has been problematic of late because Congress—perhaps in the mistaken belief that it can repeal the laws of physics—has started tampering with the requirements. Proposed standards would force many Americans into driving tiny cars that, without big breakthroughs in safety technology, would become deathtraps.

Maybe when Congress enacts environmental laws, it should merely empower rule-making bodies to create standards based on input from industry experts. The experts won't always agree, but it's hard to imagine them doing worse than Congress. The laws and the rules that flow from them should not prescribe (or proscribe) technical approaches. Rather, laws should articulate performance *goals*—not requirements. This approach would free the engineering community to create designs that meet truly significant objectives. Monitoring conformance to results-oriented regulations could take more work than monitoring conformance to mandates that require the use—or avoidance—of particular technologies. But focusing on results would be far more effective because it would not tie designers' hands or stifle creativity.

DAN STRASSBERG, SENIOR TECHNICAL EDITOR

Send me your comments via fax at (617) 558-4470, or on the EDN Bulletin Board System at (617) 558-4241, 300/1200/2400 8,N,1. From the Main System Menu, enter ss/soapbox and select W to write us a letter.

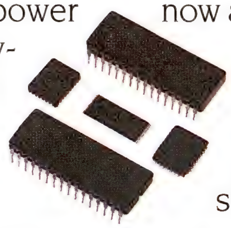
Jesse H Neal Editorial Achievement Award
1990 Certificate, Best Editorial
1990 Certificate, Best Series
1987, 1981 (2), 1978 (2), 1977, 1976, 1975

American Society of Business Press Editors Award
1994, 1991, 1990, 1988, 1983, 1981

Why Is The Industry Rallying

The people have spoken. AMD® has heard your demands for Flash technology that reduces system costs through single power supply operation. And AMD has delivered — with the Am29Fxxx family of 5.0 Volt-only Flash devices.

The response was overwhelming. The industry is lining up behind the Am29Fxxx Flash standard. Fujitsu, Motorola, and SGS-Thomson are committed to supplying compatible Flash devices. And AMD is committed to volume, now and in the future, with the world's largest, 0.5 micron Flash manufacturing facility. Which means more sources, and more Flash memories for you.



The Am29Fxxx Flash family ranges in density from 1 to 16 Mbits and includes x8/x16 user-configurable design.

Why has AMD Flash garnered such strong support? Because the Am29Fxxx family offers what engineers need. Including our patented Negative Gate

Behind AMD's Flash Family?

Erase technology for cost effective 5.0 Volt-only operation. Embedded algorithms for easy design implementation. Sector erase for flexible upgrades. JEDEC standard compliance. Even 100,000 read/write cycles — the highest reliability available. Guaranteed.

Word has definitely hit the streets about AMD Flash. So pick up the phone and get the whole story on the AMD Flash family. Contact your local AMD sales office, listed below, for our brochures and a complete Flash Data Book. And see for yourself why so many have raised their standards to those of the AMD Flash family.

Ask for Literature Pack 18X.

Advanced Micro Devices

For more information on the 29Fxxx Flash family, contact your local AMD sales office or sales representative. International Sales Offices: Antwerpen (03) 248 43 00; Frankfurt area (06172) 9267-0; Hong Kong 86 54 525; London area (0483) 740 440; Manchester area (0925) 830 380; Milano (02) 339-05 41; München (089) 45053-0; Osaka (06) 243 32 50; Paris (1) 49 75 10 10; Seoul (02) 784 0030; Singapore (65) 348 11 88; Stockholm (08) 98 61 80; Taipei (02) 715 35 36; Tokyo (03) 334 67 550.

CPUs, chip sets, and BIOS join to GREEN YOUR PC

MARKUS LEVY, TECHNICAL EDITOR

Everybody's doing it. The "green PC" no longer represents a niche market. Green PCs were first conceived and developed a few years ago by just a handful of pioneering companies. At that time, many argued that the motivation for developing green PCs was market-oriented, because customers weren't actively seeking to purchase these types of computers. Today, green PCs—and the components they comprise—proliferate every segment of the computer industry, including printers, fax machines, and a range of office equipment. The good news is that computer manufacturers are able to green their machines at little or no cost to the consumer. And the great news is the very positive impact this move has for our environment (see **box**, "PCs impacting the environment").

Although many designers may not currently be involved in developing green PCs, a time will come when we'll all at least be using them. So, regardless of your level of involvement, this article offers some insight into what's happening under the hood of your power-managed computer.

Conception of the green PC

Approximately four years ago, Phoenix Technologies and Intel conceived the 24-hour-a-day PC, later known as the green PC. Greening a PC is about saving power without sacrificing system performance. No major developments occurred in this area until 1992, when the Environmental Protection Agency (EPA) announced Energy Star, a program to encourage computer-power conservation. To be certified as Energy Star-compliant, a system must enter a low-power state when the unit is inactive (a low-power state is defined as a maximum of 30W for either the computer or the monitor). Industry pundits are hoping

Green PCs, designed to better our environment through conservation, have become the norm. Although many peripheral devices have built-in mechanisms to manage power automatically, the majority of a system's green capability can be attributed to the CPU, its associated chip set, and the BIOS.

Photo courtesy Intel Corp;
digital photography by Richard Wahlstrom Photography Inc

GREEN PC

for a second phase that lowers this number, because many 486 systems meet this specification even without power-management techniques. Nonetheless, compared with the typical 160W a combined computer/monitor operating in the active mode consumes, 30W represents a big savings. And many computer and monitor manufacturers are developing equipment that consumes far less than 30W.

Energy Star is a self-policing program: an OEM must perform all of its own tests and report accurate results. In some cases where OEMs have reported incorrect information, the companies had to modify equipment or remove the Energy Star logo. To remove ambiguities in the qualification process, the EPA defined power-consumption measuring procedures. These procedures specify test conditions ranging from ambient temperature to line impedance. As the EPA forewarned, a range of watt meters is available (some of which are inadequate), so exercise care when making your selection. Some selection criteria must be based on the meter's crest factor, frequency response, resolution, accuracy, and calibration capability.

Power-consumption profiling

In a green PC, the CPU, its associated chip set, and the BIOS have a synergistic relationship in governing power management for the entire computer system. To achieve the highest level of power management and performance, a green PC design builds a complex relationship among these three components. The BIOS and chip set must monitor system activity and determine when it's appropriate to shut down the various computer subsystems. Understanding this relationship is perhaps the key—and most difficult—aspect of power management; it's more an art than a science.

A computer system comprises many devices, including the CPU, memory, keyboard, monitor, disk drive, and so on. By examining power consumption for each of these devices separately, you learn the relative impact that each device has on the system's overall power consumption. For example, you may not be surprised to see memory consuming far less power than the disk drive or CPU. Use this power profile to determine where to focus your energy when applying power-management techniques to a design. Obviously for a battery-powered computer, the goal is to squeeze every possible (and practical) power-saving source. But in a desktop computer, the primary goal should be to target the major power hogs.

The CPU is one of those power hogs, where processors such as the Pentium can consume as much as 10 to 15W in active mode. The most obvious, but not necessarily the easiest (from a manufacturing and design standpoint), means of reducing a CPU's power consumption is to reduce its operating voltage. Manufacturers built first-generation CPUs on a 5V technology; but soon most 486- and 586-class processors will be built on a 3.3V process. Originally, CPU vendors obtained 3.3V versions by characterizing 5V devices at the lower voltage. However, in order to pass 5V parts off as 3.3V parts, they significantly derated specified operating frequencies of the 3.3V CPUs.

Newer CPUs, especially those running at 100 MHz, require 3.3V to permit faster CMOS switching times and to reduce heat generation. Today, the majority of 3.3V devices are built as 3.3V devices from the ground up, but they have 5V-tolerant outputs to support the readily available 5V logic that still dominates a PC's motherboard. Some 486 CPUs, such as the Cyrix DX2-V66 and DX2-V80, require a nominal voltage of 4V; the system needs a voltage regulator to supply this nonstandard voltage.

Current and future generations of CPUs have automatic built-in circuitry to disable clocking to nonactive execution units. For example, CPU designers commonly apply this technique to the floating-point unit, which may not always have an instruction flowing through it.

The manufacturers of 486 and Pentium processors, such as AMD, Cyrix, Intel, and Texas Instruments, have integrated several mechanisms to help achieve lower power consumption. Although these mechanisms provide similar end results, it's an interesting exercise to sort through their differences.

CPU clock control

The amount of power a CPU's circuitry consumes is linearly related to its operating frequency, $P=CV^2f$, where C is the device's capacitance, V is the difference between high and low voltage,

PCs IMPACTING THE ENVIRONMENT

Computers make up the fastest growing electricity load in the business world. The EPA has stated that a typical computer system (combined CPU, monitor, and printer) consumes 451 kWhr annually. This figure is based on a typical eight-hour workday, with 240 workdays per year. And, when compared with the 2059 kWhr per year for the system running 24 hours per day for 365 days, this represents the usage model of approximately 40% of the computers in operation. With 140 million PCs in the world today, this number expands to 153 billion kWhr used per year; to generate this energy, it takes almost 77 million tons of coal and an estimated $11 billion—an incredible impact on both the environment and the economy.

Last year, President Clinton endorsed the EPA's Energy Star program. His directive mandates that the federal government, the largest consumer of computers in the world, will purchase only Energy Star-compliant PCs. This move will save the federal government $40 million per year on reduced electricity costs; it also frees up tax dollars for other spending.

To learn more about the EPA Energy Star Computers Program, contact Jeff Webb, the Environmental Protection Agency, Energy Star, US EPA-6202J, 401 M St SW, Washington, DC 20460. Or, request an Energy Star information packet from the EPA Energy Star fax line at (202) 223-9659.

TABLE 1—REPRESENTATIVE GREEN CHIP SETS FOR 486S AND PENTIUM CHIPS

Device name	Number of chips	Processors (SMI support)	Bus*	Voltage at CPU interface	8-MHz clock	Clock-speed control (MHz)	Events monitored	Other power-management features
ACC Micro-2168GT	1	486 (A,C,I)	VESA	5	Yes	0 to 50	22	Susp/Resume button
-2178	1	486 (A,C,I)	VESA**	5	Yes	0 to 50	22	Susp/Resume button
-2268	1	Pentium	VESA **	5	Yes	0 to 50	22	Susp/Resume button
-2278	1	Pentium	VESA**	3.3/5 mixed	Yes	0 to 66	22	Susp/Resume button
Cypress-CY82-C599/597	2	486 (A,C,I)	PCI/VESA	5	Yes	0 to 50	11	Five user-defined timers
CY82-C691/692/693	3	Pentium	PCI	3.3/5 mixed	Yes	0 to 66	11	Five user-defined timers
Efar-EC802G and EC100	2	486 (A,C,I)	VL	5	Yes	0 to 50	30	Five watchdogs, independent timer for display, I/O trap and restart
EC810PB, EC802G, and EC100	3	486 (A,C,I)	PCI/VL	5	Yes	0 to 50	30	Five watchdogs, independent and EC100 timer for monitor, I/O trap and restart
Power Set	4	Pentium	PCI	3.3	Yes	0 to 66	20	Four watchdogs, independent timer for monitor, I/O trap and restart, user timer, power control port
IMS 5026/27/28 or Atmel 40511/512/513	4	Pentium	PCI	3.3	Yes	0 to 66	12	Eight power control pins, timers, shadow registers, clock throttling, seven modem ring resume
8848/8849 or Atmel 40411/412	2	486 (A,C,I)	PCI/VL	5	Yes	0 to 50	12	One timer
Intel-82420EX (Aries)	2	486 (I)	PCI	5	No	50	15	Clock throttling
82420ZX (Saturn)	3	486 (I)	PCI	5	No	33	15	Clock throttling
82430NX (Neptune)	4	Pentium (90/100 MHz)	PCI/EISA	3.3	No	50	15	Clock throttling
OPTi-82C802G	1	486 (A,C,I) & P24D	ISA	5	Yes	8 to 50	29	One timer, monitor and synch control
Viper	3	Pentium	PCI/VL	3.3	Yes	0 to 66	N/A	N/A
PicoPower-PT86C368	2	486 (A,C,I)	VL	3.3/5 hybrid	Yes	0 to 20 at 3.3V 0 to 33 at 5V	12	N/A
PT80C732	4	Pentium	VL/PCI using	3.3/5 hybrid PT80C826	Yes	0 to 40 at 3.3V 12	12 0 to 50 at 5V	N/A
PT86C768	2	486 (A,C,I)	VL/PCI using PT80C826	3.3/5 hybrid	Yes	0 to 40 at 3.3V 0 to 50 at 5V	12	N/A
PT86C868	2	486 (A,C,I)	VL/PCI using PT80C826	3.3/5 hybrid	Yes	0 to 40 at 3.3V 0 to 50 at 5V	12	N/A
Samsung K582C53X	3	Pentium	PCI	3.3/5	No	DC to 66	30	Four timers, expandable I/O for power control
SIS-85c496	2	486 (A,C,I)	PCI/VESA	5	Yes	0 to 50	11	Five PMU control timers, eight SMOUT, clock throttling
85C501	3	Pentium	PCI	3.3/5	No	33 to 66	11	Two watchdogs, clock throttling control
Symphony Labs-Puccini	3	Pentium	VL/PCI	3.3/5 mixed	Yes	0 to 66	7	GP I/O port, three watchdogs
Strauss	3	486 (A,C,I)	VL/PCI	5	Yes	0 to 66	7	GP I/O port controls power status of eight I/O devices, seven watchdogs
Wagner	2	486 (A,C,I)	VL	5	Yes	0 to 66	7	GP I/O port controls power status of eight I/O devices, seven watchdogs
VIA-Apollo	3	Pentium	PCI	3.3	Yes	0 to 66	12	Three activity timers, one GP timer, two idle timers, monitor synch control
Pluto	2	486 (A,C,I)	PCI	3.3	Yes	0 to 50	12	Three activity timers, one GP timer, two idle timers, monitor synch control
VLSI-VL82C483	1	486 (I)	ISA	5	Yes	8.3 to 50	24	Two watchdogs
590	3	Pentium	PCI/ISA Bridge	3.3	No	66	28	One watchdog

Notes: A=AMD, C=Cyrix, I=Intel. N/A=not available. *All support ISA. **Use ACC2188 for PCI.

GREEN PC

and f is the clock frequency. Within the realm of the desktop computer, slowing the clock speed was the original method used for controlling a CPU's power consumption. Nonstatic 486 processors can have clock speeds drop to 8 MHz during periods of inactivity without adversely affecting the device's operation (recently, some Intel devices have been derated to 12 MHz). Furthermore, because these devices were not static, the only way to suspend the CPU fully was to remove power. To accomplish this, the CPU's entire state had to be saved to disk. Not surprisingly, very few desktop systems implemented a full suspend. Today, most 486 and Pentium CPUs are static, allowing the clock rate to stop without state loss.

Clock-doubling and -tripling CPUs available today utilize a phase-locked loop (PLL) to synchronize the external clock signal and produce a stable clock for the CPU's internal circuitry. Jitter is an inherent problem with any PLL, typically taking 1 msec to tune itself after any input clock change of greater than 0.1%. However, usually by the time the system decides to lower the clock, the system was already idle, and the user shouldn't experience a performance degradation.

Texas Instruments' clock-doubled SXL2 and SXLC2 486 CPUs incorporate a gated PLL that allows quick recovery from clock changes. A control signal within the processor allows the clock signal to bypass the PLL to enable clock frequency switching without any latency. The Enable Clock Double bit in configuration register CCR0 enables PLL bypassing. In a standard implementation, these 486s run at 50 MHz internally while the system bus runs at 25 MHz. Bypassing the PLL, the CPU immediately begins running internally at 25 MHz, resulting in a two-times power reduction. While in this mode, the external clock can vary to any frequency without PLL synchronization delays.

When Intel's now-obsolete 386SL arrived on the scene in 1990, the device introduced new power-management techniques for notebook computers. Some of these techniques have evolved and proliferated throughout most 486 and Pentium products; in addition, designers use them extensively to green most desktop computers. One of those techniques, which Intel 486s and Pentium chips use, utilizes a special pin on the CPU, called STPCLK. When the CPU samples an active STPCLK input, it stops the clock to the core but keeps the PLL active. While STPCLK is active, clock signals to memory and cache control, and external bus control units remain active, but the CPU consumes only 15% of its normal operating power. While STPCLK asserts, the Pentium still responds to interprocessor and external snoop requests. After the STPCLK signal deasserts, it takes a few clocks to return to normal execution; for example, the Pentium takes approximately 10 clock periods.

Cyrix and TI 486s use a slightly different method for activating such a low power mode. These processors do not have a STPCLK input. Instead they use suspend (SUSP) and suspend-acknowledge (SUSPA) signals, which power-down all logic except that associated with monitoring the CPU's RESET, HOLD, and FLUSH inputs. In addition, a HALT instruction causes all 486s and Pentium CPUs (except AMD's 5V 486s) to enter the suspend state. This suspend state will terminate on occurrence of attention-needing signals such as INTR, NMI, and SMI (system-management interrupt).

Another power-management mechanism the 386SL brought to the party is system-management mode (SMM), which enables code to control CPU power without having to rewrite or revamp existing operating-system software. SMM is entered via the hardware interrupt; SMI enters SMM. The SMI interrupt code can set SMM operating modes to reduce CPU and subsystem power dissipation. The SMM code, as well as the processor state, is kept in a separate memory space called system-management RAM (SM-RAM). Separating memory spaces allows the SMM to operate without intruding on normal CPU operation or system memory.

Using SMM in desktops has led to the distinction between light- and dark-green PCs. Light green refers to systems that rely strictly on the keyboard or mouse to wake them. This relationship presents a limitation for unattended systems on networks or with modems on autoanswer that need to be awakened by other I/O activity. Using SMM, dark-green PCs can wake up on any I/O activity that generates an SMI.

The method of SMM implementation varies among different 486 man-

TABLE 2—REPRESENTATIVE POWER CONSUMPTION FOR SMM-SUPPORTING CPUs[1]

Device	Voltage	Frequency (MHz)	Power (W) active max	Power (W)[2] suspend max	Power (W)[3] stop clock
AMD-DXL2	5	80	7.5	1.17	N/A
AMD-DX4	3.45	100	5.0	0.14	N/A
Cyrix-DX	5	66	6.6	0.17	0.005
Cyrix-DX2-V	3.45	50	2.9	0.09	0.034
Cyrix-DX2-V	3.8	66	4.4	0.13	0.038
Cyrix-DX2-V	4.0	80	5.2	0.15	0.04
Intel-Pentium	3.3	100	10.1	1.55	0.09
Intel-SX	3.3	33	1.2	0.16	0.003
Intel-SX	5	33	3.2	0.4	0.01
Intel-DX	3.3	33	1.2	0.16	0.003
Intel-DX	5	50	4.5	0.5	0.01
Intel-DX2	3.3	50	1.7	0.16	0.003
Intel-DX2	5	66	5.7	0.45	0.10
Intel-DX4	3.3	100	4.3	0.33	0.003

Notes: 1. Power numbers derived from corresponding maximum values by multiplying ICC by the device's input voltage.
2. For AMD, this number represents its 8-MHz clock-reduced mode.
3. AMD does not support this mode.
4. N/A=not applicable.

The family just keeps growing.

Our newest arrival, MPX5010D Signal Conditioned Pressure Sensor, with a pressure range of 0-10 kPa (0-1.45 psi), is well suited for microcontroller or microprocessor-based systems A/D inputs.

Motorola's MPX5100 family of monolithic pressure sensors is multiplying like you-know-what. Which means whatever your sensing needs, chances are we've got the device to do the job.

Take our new MPX5010D fully signal conditioned, temperature compensated from 0°C to 85°C and calibrated silicon pressure sensor. It's particularly suited for applications that employ a microcontroller or microprocessor with A/D inputs. In fact, it and the rest of our MPX5000 Series pressure sensors make perfect sense for a wide range of applications, including consumer instrumentation, level indicators, inflation monitoring, pressure switching, pressure control systems, respiratory diagnostics, and heating, ventilating and air conditioning.

Motorola's patented, single element X-ducer™ combines advanced micromachining techniques, thin film metallization and bipolar semiconductor processing, designed to provide an accurate, high level analog output signal that is proportional to applied pressure. The MPX5010 Series Pressure Sensors are available in differential and gauge configurations—either in the basic element package or with pressure port fittings that provide printed circuit board mounting ease and barbed hose pressure connections.

Look into the MPX5010D

- *On-chip bipolar amplification offers high level analog output (0.2 V to 4.7 V)*
- *Pressure range: 0-10 kPa (0-1.45 psi)*
- *Temperature compensated over 0°C to 85°C*
- *8 standard porting options*
- *Patented silicon design*
- *Epoxy unibody element*
- *High volume manufacturing capability*

Contact Us. And Hop to It!

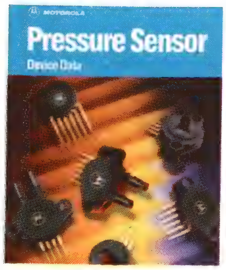
For more information, send the coupon below, or write Motorola Ltd., European Literature Centre, Tanners Drive, Blakelands, Milton Keynes MK14-5BP, United Kingdom. Please request Pressure Sensor Device Data Book #DL200/D Rev. 1.

X-ducer is a trademark of Motorola, Inc.

MOTOROLA

Motorola and Ⓜ are registered trademarks of Motorola, Inc.

To: Motorola Ltd., European Literature Centre, 88 Tanners Drive, Blakelands, Milton Keynes MK14-5BP, United Kingdom.



Please send me Pressure Sensor Device Data Book #DL200/D Rev 1.

651EDN111094

Name ______________________

Title ______________________

Company ______________________

Address ______________________

City ____________ State ________ Zip ________

Call Me (   ) ______________________

GREEN PC

ufacturers. Regardless of the implementation, SMI execution involves four distinct phases:

1. An SMI signal is generated in response to system interrupts that monitor system activity or inactivity. The SMI is the highest priority non-maskable interrupt (higher than NMI). This interrupt cannot be reentered, and the CPU won't recognize additional SMIs until exiting from SMM.

2. The processor automatically saves its state to a fixed location within the SM-RAM space; this location varies for each manufacturer's processor. For example, AMD 486s save the processor state in the address range of 60000H-601A7H. TI's CPUs save at the top of the defined SMM space. This state-saving process is similar to a normal interrupt except that an SMI goes well beyond saving the current execution point and status. The amount of saved information, and therefore the time to enter SMM, varies per manufacturer.

3. The SMM code executes out of SM-RAM (**Fig 1**). This code, which is contained in the SM-RAM, must be initialized prior to first execution of an SMI.

4. An SMI terminates by executing a new instruction called Resume Normal Mode (RSM). This operation restores the original processor state, and normal operation resumes. Of course, if the HALT instruction were executed in the SMM handler, the CPU would be stuck in the SMI until a non-SMI occurs.

The SMM implementation, first appearing on Intel's SL products, has now proliferated throughout the company's entire 486 and Pentium product lines. For this reason, Intel refers to current 486s as SL-enhanced versions; their implementation utilizes two pins, SMI and SMI active (SMIACT). After the CPU recognizes the SMI, it asserts SMIACT, which the system logic uses to decode accesses to the separate SM-RAM. All other bus signals are identical to normal access mode. Texas Instruments' 486s use a similar approach with SMI and SMADS (address strobe) signals. While in SMM, TI 486s can use new instructions they've added to access non-SM-RAM; during these accesses, the CPUs generate the standard ADS signal while SMADS remains inactive.

AMD was first to implement SMM in a non-SL device, but, unlike Intel's approach, AMD chose a three-pin implementation. After the CPU recognizes the SMI, it begins driving the SMI signal to indicate to the system that it has entered into SMM. However, this signal should not be used to qualify SMM accesses because it remains active

MANUFACTURERS OF GREEN CPUs, CHIP SETS, AND BIOSs

For free information on the products or technologies described in this article, circle the appropriate numbers on the postage-paid Information Retrieval Service card or use *EDN*'s Express Request Service. When you contact any of the following manufacturers directly, please let them know you saw their products in *EDN*.

486 or Pentium processors

Advanced Micro Devices (AMD)
Austin, TX
(512) 462-4360
Circle No. 333

Cyrix Corp
Richardson, TX
(214) 234-8388
Circle No. 334

IBM Microelectronics Inc
Fishkill, NY
(800) 426-0181
Circle No. 335

Intel Literature Center
Mount Prospect, IL
(800) 468-8118
Circle No. 336

SGS-Thomson Microelectronics
Phoenix, AZ
(602) 867-6200
Circle No. 337

Texas Instruments Inc
Literature Response Center
Denver, CO
(800) 477-8924, ext 4500
Circle No. 338

Chip sets

ACC Microelectronics Corp
Santa Clara, CA
(408) 980-0622
Circle No. 339

ALI
Santa Clara, CA
(408) 764-0644
Circle No. 340

Atmel
San Jose, CA
(408) 436-4295
Circle No. 341

Cypress Semiconductor Corp
San Jose, CA
(408) 943-2600
Circle No. 342

Efar Microsystems Inc
Santa Clara, CA
(408) 496-1888
Circle No. 343

Integrated Micro Solutions Inc (IMS)
San Jose, CA
(408) 954-0818
Circle No. 344

OPTi Inc
Santa Clara, CA
(408) 980-8178
Circle No. 345

PicoPower Technology
San Jose, CA
(408) 954-9898
Circle No. 346

Samsung Semiconductor Inc
San Jose, CA
(408) 954-6972
Circle No. 347

Silicon Integrated Systems Corp
Sunnyvale, CA
(408) 730-5600
Circle No. 348

Symphony Laboratories
Santa Clara, CA
(408) 986-1701
Circle No. 349

UMC Microelectronics Corp
Taipei, Taiwan, ROC
886-2-918-1589
Circle No. 350

VIA Technology
Fremont, CA
(510) 683-3316
Circle No. 351

VLSI Technology Inc
Tempe, AZ
(602) 752-8574
Circle No. 352

BIOSs/OSs

American Megatrends Inc
Norcross, GA
(404) 263-8181
Circle No. 353

Award Software International Inc
Mountain View, CA
(415) 968-4433
Circle No. 354

Microsoft Corp
Redmond, WA
(800) 426-9400
Circle No. 355

Phoenix Technologies Ltd
Norwood, MA
(617) 551-4000
Circle No. 356

SystemSoft Corp
Natick, MA
(508) 651-0088
Circle No. 458

For information on these vendors' products, circle just one number on the reader service card. Circle No. 459

GREEN PC

even when using the special instructions that access non-SM-RAM. The CPU uses two additional pins, SMI address status (SMIADS) and SMI ready (SMIRDY), for bus cycles to the SM-RAM. These two pins are analogous to ADS and RDY used in normal bus cycles.

One final note on CPU power management: next-generation, 586-class processors from AMD and Cyrix are expected to be pin compatible with Intel's Pentium (including SMI, SMIACT, and STPCLK). The implementation may differ internally, but, at least from a socket perspective, this compatibility allows easier acceptance into the already established Pentium market.

Green chip sets

Chip sets with power-management capability originally targeted notebook computers. Some of these notebook-chip-set manufacturers still sell these enhanced power-managed devices for green-PC designs, and others have either upgraded their existing desktop chip sets or developed entirely new green devices. The most noticeable differences between notebook and green-PC chip sets are the number of peripheral devices the chips sets monitor or control or the number of power-managed modes (ie, sleep, doze, etc). In a notebook computer, where every drop of battery life is crucial and customers are willing to pay a premium, the chip sets tend to be more robust. However, as the competition heats up, chip-set manufacturers are adding more capabilities (at lower prices) to help differentiate their products. You'll find this especially true in the mature 486 market.

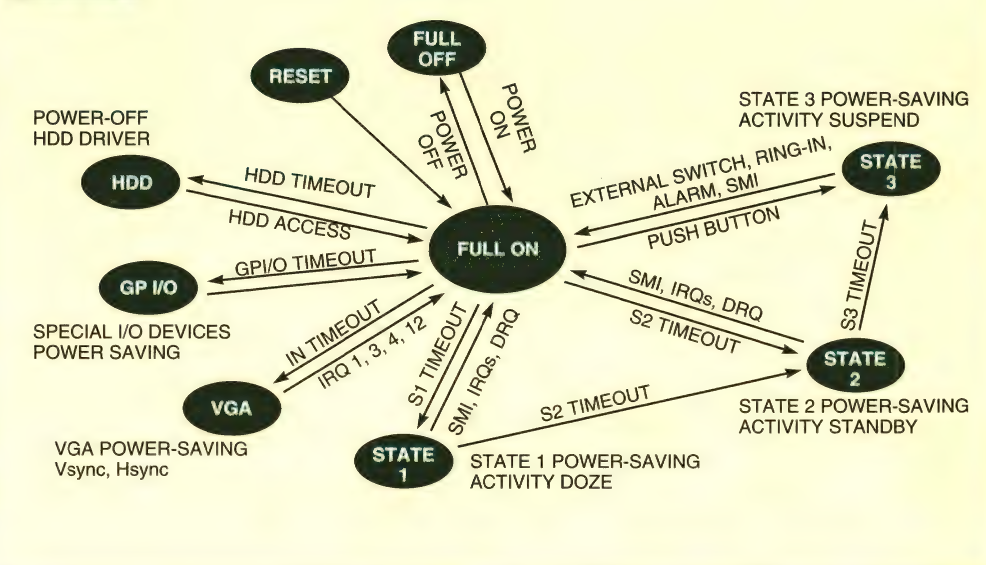
The chip sets are actually the workhorses that control a system's power management. At the simplest level, they provide SMI, STPCLK, and SUSP signals. They also offer hardware monitoring and control of various system activities. Almost all chip-set manufacturers have devices that support green-PC designs. Focusing on power-management capabilities, each green chip set has variations of the following:

- SMM support: As a minimum, all chip sets that perform this function support Intel's SMI/SMIACT approach. Most chip sets also support the three-pin AMD and Cyrix approach by multiplexing functionality on certain pins. There are special registers within the chip sets for selecting mechanisms, and the system BIOS is responsible for programming the registers on system initialization. BIOSs that support this capability contain algorithms to determine what type of CPU is present. This function allows PC OEMs one-stop shopping when purchasing a BIOS that works with any processor.
- Most chip sets support an "auto-green" mode to accommodate non-SL-enhanced and nonstatic CPUs. Because these CPUs are not static devices and because they have no SMM capability, this mode slows the CPU's clock to 8 MHz. Other related features may include CPU clock-scaling, throttling, and stop-clock control. Most green chip sets support the various software-controlled power-level modes such as doze, sleep, suspend, full speed, etc (**Fig 2**).
- All chip sets have one or more timers used in conjunction with hardware inputs to monitor system events. These events represent system accesses to video, floppy and HDD, serial and parallel ports, keyboard, DMA, an external input, and general-purpose memory and I/O. For an example of how this works, consider memory-access monitoring. At system initialization, the BIOS programs a specific register (or registers) within the chip set with a certain memory address range. It will also program a corresponding timer with a time-out value; this value may be user-determined or supplied as a system default and typically ranges from 1 sec to 300 minutes. The chip set monitors every access to this memory range, and each time it's accessed, the timer resets. If the memory is not accessed within the period of the time-out value, the chip set generates an SMI, causing the CPU to enter SMM and perhaps shut off power to memory.
- For those of you who leave your PC running while you go out for lunch, some chip sets include an asynchronous input, referred to as external SMI, which connects to a "coffee-break" button on the PC.

Software's role

The system BIOS directly supports the hardware features of a chip set as well as the different CPUs. Although some PC OEMs have their own BIOS

FIGURE 1



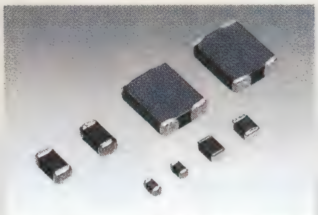
Implementations of an SMI handler vary depending on the chip set, CPU, system peripherals, BIOS, or any OEM differentiating features.

Best Performance in a Supporting Role

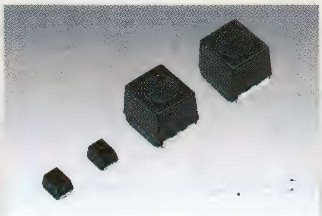
Just as every great production requires full cast support, the competition for higher density, higher frequency electronics demands a decisive performance from every component.

With TOKIN Surface Mount Devices (SMDs), that's exactly what you get. Whether it's transformers or inductors, or any of the broad range of suppressors and capacitors, TOKIN SMDs handle each new application with aplomb.

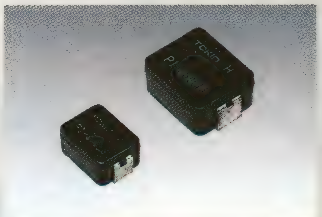
So call TOKIN, then watch your returns—and critical acclaim—soar.



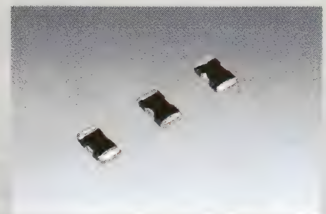
Solid Chip EMI Filters and Common Mode Choke Coils



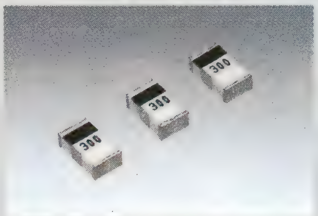
Wire-wound Chip Inductors



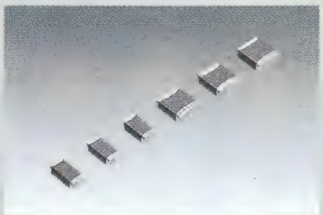
SMD Power Inductors



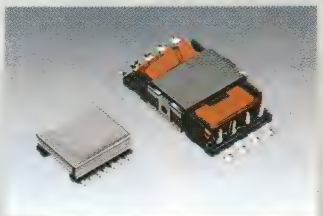
Three-terminal Filter Capacitors



Three-terminal EMI Filters



*Multilayer Ceramic Chip Capacitors



SMD Transformers

*Available only in the United States.

TOKIN

Tokin Corporation
Head Office
7-1, Koriyama 6-chome, Taihaku-ku, Sendai, Miyagi-ken 982 Japan
International Sales Department
Sumitomo Seimei Sendai Chuo Bldg., 6-1, Chuo 4-chome, Aoba-ku, Sendai 980, Japan
Phone: 022-211-1281 Fax: 022-211-0975
Korea Representative Office
#602, Champs-Elysees Bldg., 889-5, Daechi-Dong, Kangnam-gu, Seoul, Korea
Phone: (2) 569-2582~5 Fax: (2) 544-7087

Tokin America Inc.
155 Nicholson Lane, San Jose, California 95134, U.S.A.
Phone: 408-432-8020 Fax: 408-434-0375
Chicago Branch
9935 Capitol Drive, Wheeling, Illinois 60090, U.S.A.
Phone: 708-215-8802 Fax: 708-215-8804

Tokin Electronics (HK) Ltd.
Unit 705-707, Chiwan Tower, Park Lane Square, 1 Kimberly Rd., Tsim Sha Tsui, Kowloon, Hong Kong
Phone: 730-0028 Fax: 375-2508
Taiwan Liaison Office
Phone: (02) 7728852 Fax: (02) 7114260
Singapore Branch
Phone: 2237076 Fax: 2236093, 2278772
Shanghai Liaison Office
Phone: 21-433-4488 Ext. 80809 Fax: 21-433-3265 Ext. 80809

Tokin Europe GmbH
Knorrstr, 142, 80937 München, Germany
Phone: 089-311 10 66 Fax: 089-311 35 84

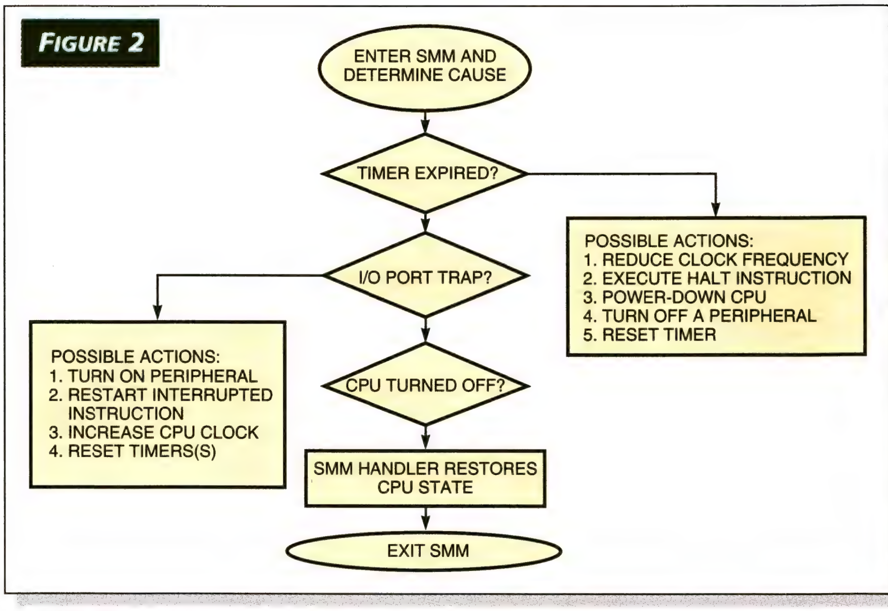
CIRCLE NO. 210

GREEN PC

groups, most OEMs use the services of the four major BIOS vendors (American Megatrends Inc, Award Software, Phoenix Technologies, and SystemSoft Corp), whose products support most commercially available chip sets and their power-management features.

Microsoft, Intel, and Phoenix defined an application-program interface called Advanced Power Management (APM), which lets an application running Windows 3.1 communicate with the power-management portion of a system's BIOS. During system software operation, the operating system or application program, which uses the APM to pass control to the BIOS, can detect an idle condition. The BIOS, in turn, writes a special command to the chip set. The chip set then generates an SMI to the CPU, causing it to enter SMM, which begins by determining the

FIGURE 2



ALI's M1429G is a green chip set for the 486. The chip set accommodates many common software-controlled power-level modes. These modes include the usual doze, suspend, standby, and full speed.

cause of the SMI. In this case, the cause is determined as a request for global or local standby. Local standby refers to device-specific activities (or lack of) such as the hard drive. Global standby is platform-wide and often results in turning off the CPU.

On a desktop PC, the open architecture makes it difficult to enter into a completely suspended state. The danger stems from certain add-in cards or PCMCIA cards. Ethernet cards are one such example, because the suspend state severs the network connection. To handle this, the BIOS vendors are working with the OS providers to make "green-aware" OSs that can handle turning off peripherals. This scenario is a Catch-22 because, without power, the peripheral couldn't generate an SMI, which would turn the peripheral back on. Stop-clock modulation, available with many chip sets, provides one method for eliminating this suspend problem. The chip set can apply a duty cycle to the stop-clock signal when the system is idle (determined by the BIOS and APM); the system wakes up on a periodic basis to respond to the timer tick or to poll a network card.

An alternative benefit to being able to achieve a suspended state in the desktop is handling the problem of losing power (and having to say farewell to the document you neglected to save). Designers could build a system to use any remaining energy to save the state before going down. Although this sounds attractive, it's uncertain whether customers will opt for the added cost.

It's amazing to think about how the power-hungry, immense computer systems of our yesteryear have evolved. Today's powerful computers, small enough to fit on our desktops, with little or no effort, consume fractions of the energy. Compared with just a year ago, you now have many hardware and software options to support your green-PC design efforts and continue the evolution. EDN

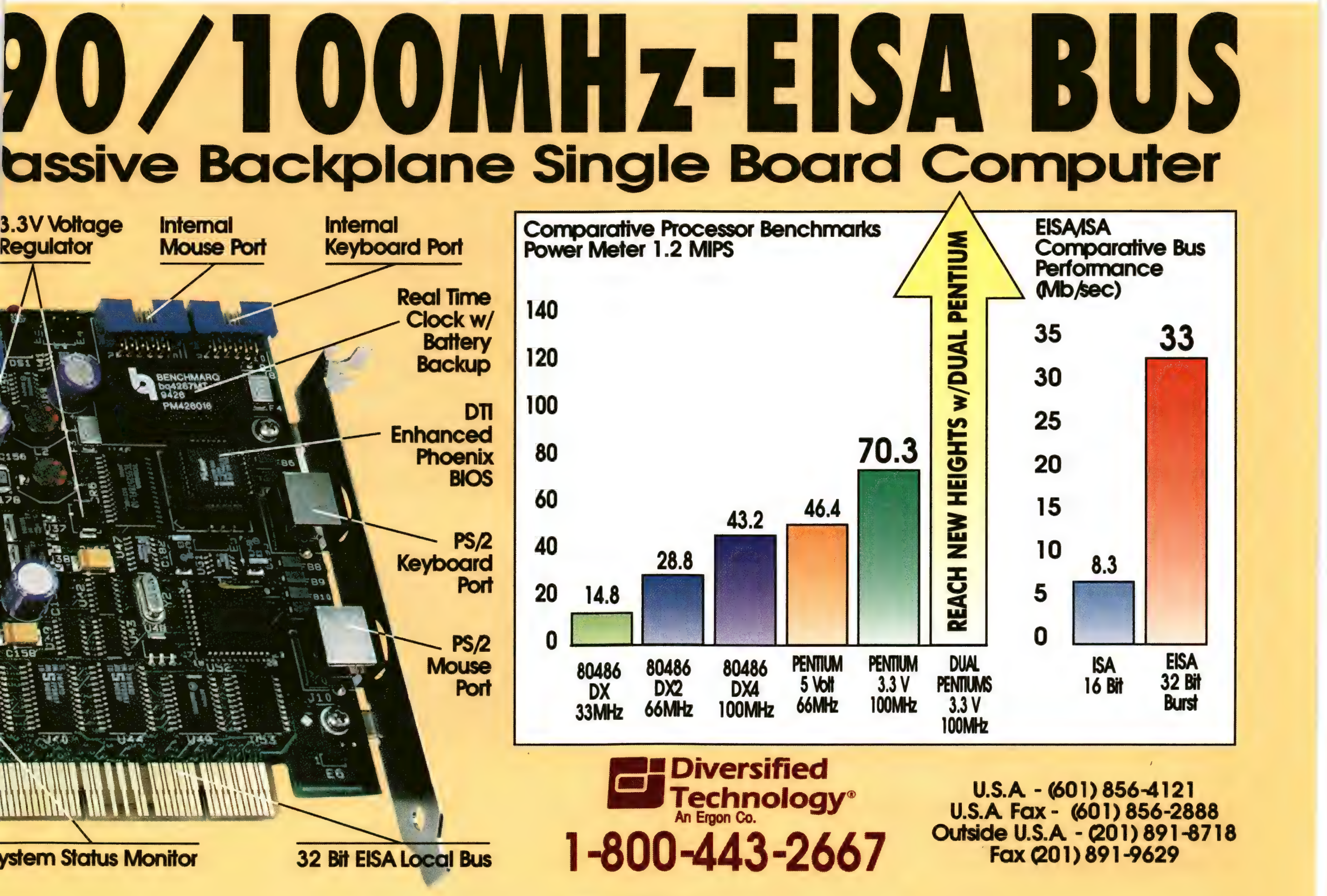
References

1. Gallant, John, "PC Power Management," *EDN*, October 15, 1992, pg 114.
2. Anzovin, Steven, "The Green PC," Windcrest/McGraw-Hill, Blue Ridge Summit, PA. $19.95.
3. Bunnell, James C, "Power Management That Works," Annabooks, San Diego, CA. $24.95.

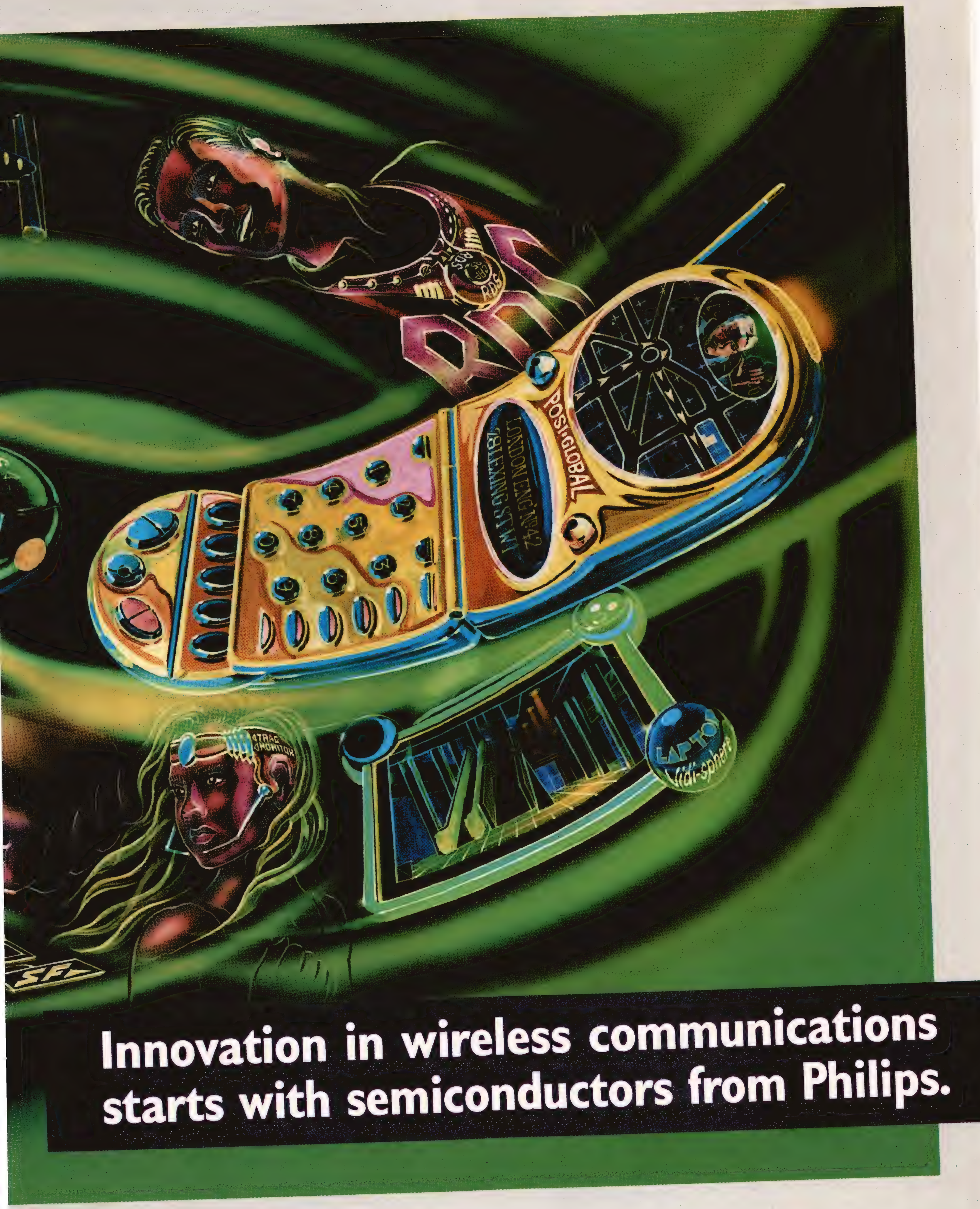
VOTE

Please use the Information Retrieval Service card to rate this article (circle one):

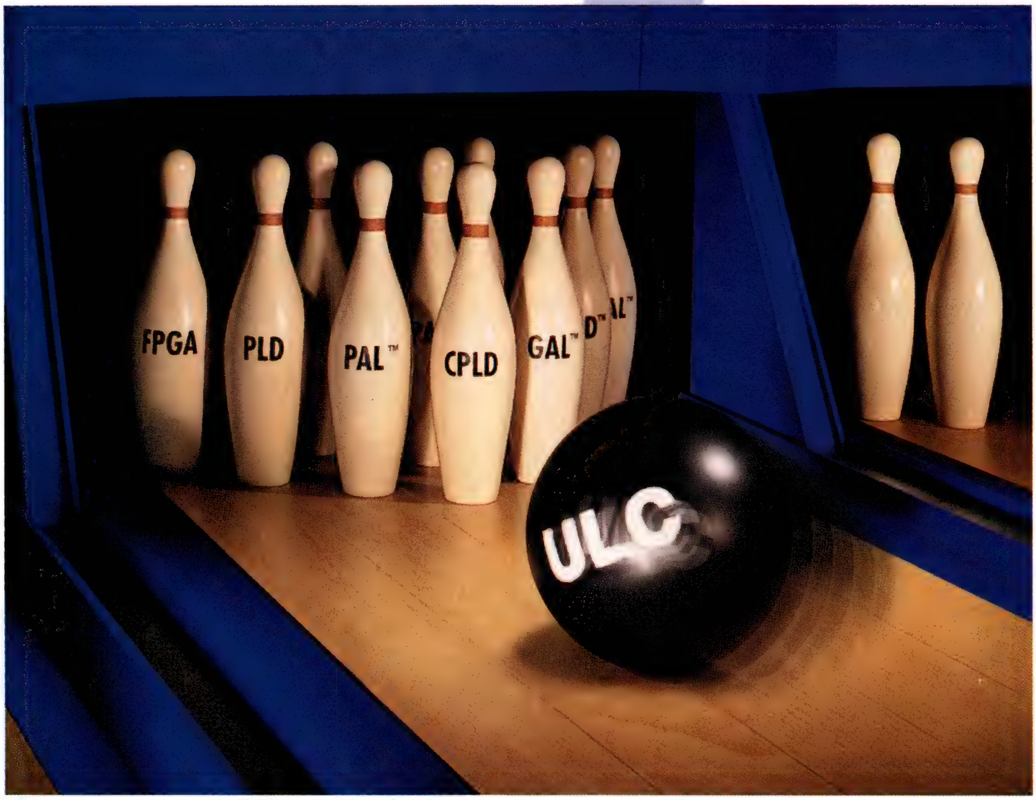
High Interest	Medium Interest	Low Interest
592	593	594



CIRCLE NO. 33


POSI-GLOBAL
Innovation in wireless communications starts with semiconductors from Philips.

ULCs™ from MATRA MHS :
The low-cost, risk-free breakthrough in PLD and FPGA conversion.



ULC™ is a trademark of MATRA MHS.

If you're tired of paying high prices for FPGAs and PLDs, it's the right time to switch to ULCs™ from MATRA MHS (ISO 9001 certified).

Our Universal Logic Circuits offer a guaranteed, risk-free alternative to any Programmable Logic Device. What's more, they can lower your component costs by a stunning 25 to 75%.

ULCs™ provide the following benefits :

- no NRE,
- no risk (simply cancel your order if the prototype doesn't work),
- no sign-off requirements thanks to patented "Verify Before Silicon" technology,
- total pin-to-pin compatibility with any PLD,
- low power 3.3V version available.

Because we undertake all conversions based on your existing inputs, including FPGA/PLD files, Master Unit and Simulation files (when available), no other solution is easier and more hassle-free for you.

ULC™ conversions are available for the full range of FPGAs and PLDs.
Every solution features unsurpassed dependability.
In fact, our ULC™ family enjoys a proven track record of over 500 successful conversions.
To find out how you can break through to lower component costs, call us today at :

1-800-554-5565, ext. 916

TEMIC

A Company of
AEG Daimler-Benz Industrie

CIRCLE NO. 108

Members of the TEMIC Semiconductor Division : Telefunken Semiconductors, Siliconix, Matra MHS, Dialog Semiconductor

TEMIC Sales Offices
FRANCE : Tel. (33) 1-30 60 71 08 - GERMANY : Tel. (49) 7131 67-0 - ITALY : Tel. (39) 2-332 121
SCANDINAVIA : Tel. (46) 8-733-0090 - UNITED KINGDOM : Tel. (44) 344-485757
HONG KONG : Tel. (852) 378-9789 - JAPAN : Tel. (81) 3-5562-3321
USA : 2201 Laurelwood Road, Santa Clara, CA 95056 - Tel. (408) 748-93 62 - Fax : (408) 748-04 39

See us on Stand A 05, Hall
at Electronica
8-12 November,

Environmental concerns are changing much in our society—including the design of portable electronic products.

GREEN BATTERIES: changing the rules for design

DAN STRASSBERG, SENIOR TECHNICAL EDITOR

Designing battery-powered electronic products—especially battery-powered consumer electronic products—will never be the same as it used to be. A decade or so ago, few people thought about the toxic materials within many batteries or what happens when those materials enter the waste stream. Efforts to manage such materials now affect how manufacturers are (or should be) designing battery-powered products. Reducing the use of toxic materials has caused changes in certain types of batteries and the disappearance of others. (See **box**, "Where have all the Hg cells gone?") Most of all, because recycling seems to be the best way to deal with several kinds of nonautomotive rechargeable batteries, the battery industry has had to make lasting changes in some of its methods.

Generally, manufacturers should no longer design products in ways that keep users from easily replacing "worn-out" rechargeable batteries. This is the case with consumer products. For these, several states have enacted laws or adopted regulations that require easy battery replacement. Having such rules in even one populous state was enough to discourage manufacturers from designing products that users would have to discard when the batteries no longer could hold a charge. (For example, some manufacturers used to make cordless vacuums this way.) The rules for industrial products are less clear-cut, but there appear to be few good reasons to design such products with rechargeable batteries that users can't replace.

In addition, manufacturers must comply with labeling requirements: The chemistry of rechargeable batteries (NiCd, for

The easiest way to tell if the Rechargeable Battery Recycling Corp's (RBRC's) industrywide recycling program handles a rechargeable battery is to look for the RBRC's seal on the battery, the unit that uses it, and the unit's packaging. The battery's chemistry (NiCd, in this case) appears beneath the seal. Variations of the seal allow its use in several sizes, although the seal doesn't fit on some very small cells. Manufacturers of products that use such tiny cells must place the seal near the battery.

example) must appear on the outside of a product containing the battery, on the product's packaging, and on the batteries themselves. If a battery is too small to bear the chemistry markings, the equipment manufacturer must mark the chemistry on the part to which users attach replacement batteries.

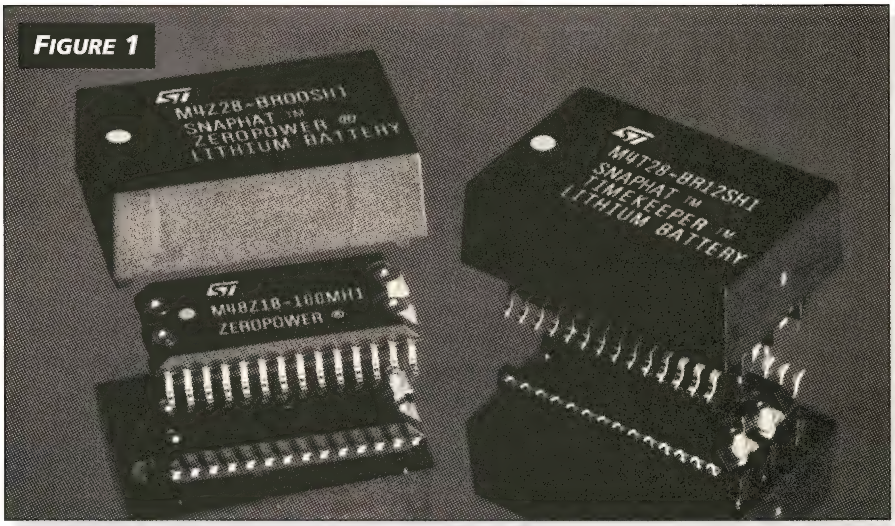
Bye-bye, soldered-in batteries

Soldering a battery to a pc board is no longer a good idea. It certainly isn't a good idea in a consumer product that uses a battery requiring recycling or reclamation. Sure, you can claim that a whole plug-in board is recyclable, but you could have problems getting battery recyclers to accept an assembly of which a battery is but a small part. If recyclers won't handle the assembly or if they balk at doing so at an affordable price, your company will probably have to set up its own recycling program. An interesting question is how recyclers will deal with "smart-batteries" (**Ref 1**), which include µPs and LCDs.

SGS-Thomson's Snaphat package (**Fig 1**) appears perfect for making pc-board-mounted batteries replaceable. The company developed Snaphat for reasons unrelated to recycling. The package enables designers to place nonrechargeable lithium (Li) batteries on surface-mount pc boards where reflow soldering would otherwise expose the batteries to excessive temperatures. Such nonrechargeable batteries are currently the only ones available in the Snaphat package. There are two types, each designed for a specific IC. Prices begin at $1.76 (10,000). Use of the package for rechargeable batteries that require recycling could solve a major problem, however.

Compared with many other industries, the battery industry has acted responsibly in the current climate of

FIGURE 1



Although developed for purposes unrelated to recycling and currently available only with nonrechargeable batteries, SGS-Thomson's Snaphat package could be used for rechargeable batteries that require recycling. Unlike batteries soldered to pc boards, Snaphat batteries snap out, obviating the need to recycle whole boards.

WHERE HAVE ALL THE HG CELLS GONE?

Mercury (actually, mercuric-oxide—HgO) button cells were nice. They had this neat characteristic: Their terminal voltage stayed nearly constant at 1.34V right to the end of their life, when it would drop precipitously. With these cells, you didn't need a voltage regulator, even for such voltage-sensitive applications as powering a light meter in a camera. Another favorite application was as a power source for hearing aids. There, the constant output voltage made it unnecessary to adjust the volume as the cells aged.

Alas, such cells are just about extinct because of their Hg content. Although Varta and perhaps others continue to supply them (see **box**, "For free information..."), 13 states have banned the sale of these cells. So, now what? The savior of this situation is product obsolescence. Hearing aids have a relatively limited life. Technological advances render them obsolete after a few years, and the operating environment (the human body) and the frailty that results from the aids' high level of miniaturization lead to their eventual deterioration. When a hearing aid reaches the end of its life, the user purchases a new hearing aid that uses another kind of battery.

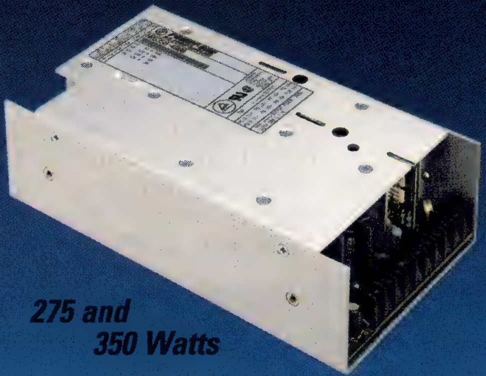
Cameras are a different story. They can have very long lives. Moreover, users of these (sometimes nearly priceless) inanimate objects develop relationships with them that perhaps only owners of English and Italian automobiles can appreciate. What do you do when the time comes to replace the Hg cell that runs the light meter in a no-longer-manufactured camera to which you've become attached?

The day is fast approaching when you will have only a few choices: Although using an external light meter is an option in many cases, using one changes the camera's "feel." Some cameras may be able to use silver-oxide button cells, even though such cells' output (1.85V, theoretically) is somewhat higher and their life is not equivalent. Or you can put the camera on a shelf or donate it to a museum where others can admire it. A collector might even be willing to buy it. Alternatively, if you're adept at working with miniature electronic parts, you could modify the camera to use a different type of cell and a micropower IC regulator. There is little likelihood that you would be able to fit the cell/regulator combination where the old button cell fit, however.

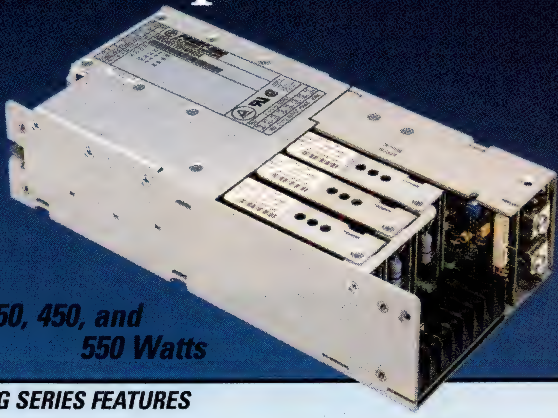
Since a lot of those old cameras still exist, you might think there'd be a business opportunity waiting to be tapped by an entrepreneur able to create a drop-in replacement for Hg button cells. Unfortunately, the market isn't large and is shrinking all the time, and the investment—particularly in production tooling—is far from trivial. As far as we can tell, until now, nobody who has looked at this "market" has been able to justify the cost of entering it.

Power-One

One tough mid-range power supply with the DVT data to prove it.



275 and 350 Watts



350, 450, and 550 Watts

NRG Series Design Verification Testing (DVT) reports are available to qualified customers. This report includes vibration, temperature, electrical overstress, and humidity test data. Power-One has pre-qualified the NRG series so you won't have to.

Call today to get your catalog and DVT report at 800-693-0212.

NRG SERIES FEATURES

- Autoselect AC input
- Remote sense on main output
- AC power-fail signal
- Fully regulated outputs
- Output good signal on main output
- VDE & FCC level B and VFG243 EMI

NRG275 AND NRG350 – 275 and 350 Watts

Floating 3rd and 4th outputs can be referenced as + or – to provide 40 possible voltage/current combinations from the following 11 models. 2nd outputs have 16A peak current capabilities.

MAX WATTS	OUTPUT 1	OUTPUT 2	OUTPUT 3	OUTPUT 4	MODEL
275	5V@25A	12V@10A	12V@6A	—	NRG275-3000
275	5V@25A	12V@10A	12V@6A	5V@2A	NRG275-4000
275	5V@25A	12V@10A	12V@6A	12V@2A	NRG275-4001
275	5V@25A	12V@10A	12V@6A	24V@2A	NRG275-4002
275	5V@25A	12V@10A	12V@6A	48V@1A	NRG275-4003
350	5V@35A	12V@10A	12V@6A	—	NRG350-3000
350	5V@35A	12V@10A	12V@6A	5V@3A	NRG350-4000
350	5V@35A	12V@10A	12V@6A	12V@3A	NRG350-4001
350	5V@35A	12V@10A	12V@6A	24V@3A	NRG350-4002
350	5V@35A	12V@10A	12V@6A	48V@1A	NRG350-4003
350	24V@10A	5V@10A	15V@4A	15V@4A	NRG350-4201

Overall size: 9"x5"x2.5", fan option adds 1.5" to length.

NRG3, NRG4, & NRG5 – 350, 450 and 550 Watts

Up to seven modular outputs are available in over 100,000 voltage/current combinations. Call our technical support department for configuration assistance.

COMPONENT	RANGES AVAILABLE
Chassis	350, 450 and 550 watts
Main modules	5, 12 and 24 volts
Auxillary modules	2, 5, 12, 15 and 24 volts, single and dual outputs

NRG3 and NRG4 overall size: 10.5"x5"x2.5", fan option adds 1.5" to length.
NRG5 overall size: 12"x5"x2.5" including standard fan.

ISO 9000 CERTIFIED™

POWER-ONE™ POWER SUPPLIES

740 Calle Plano • Camarillo, CA 93012 • (800) 693-0212 • FAX (805) 388-0476

CIRCLE NO. 49

GREEN BATTERIES

environmental concern, even though regulators have not made life particularly easy for battery vendors. Battery makers have succeeded in substantially removing mercury (Hg) from the most common nonrechargeable (primary) cells, often called dry cells: alkaline (now the most common kind) and the older "general-purpose" and "heavy-duty" types. (This article uses the terms "battery" and "cell" interchangeably. Technically, though, a cell is the fundamental building block of a battery, which comprises multiple cells.) All of these dry cells use electrodes made of manganese-dioxide (MnO_2) and zinc (Zn). The cell types differ in material purity, electrolyte composition, and construction details.

You may wonder what mercury was doing in such batteries at all. Manufacturers added the heavy metal because it reduced hydrogen (H_2) outgassing from the electrodes. The most pronounced effect of the evolution of H_2 in these batteries was ruptured cases and leakage of corrosive electrolytes, which often ruined the product that held the battery. Manufacturers first found that they were using more Hg than they had to; initial reductions in Hg content did not affect battery characteristics. Thanks to redesigned construction and changes in the chemical additives and other materials, the only traces of Hg in dry cells today are minute amounts of impurities.

The "no-mercury-added" versions of dry cells cost users no more than their predecessors did; the new batteries also offer greater shelf life and, in most uses, longer service life. The removal of Hg has enabled consumers, but not necessarily industrial users, to continue disposing of dry cells (and batteries that contain the cells) as ordinary household waste.

European countries, which first proposed regulating the Hg content of batteries, provided the impetus for these changes. Several US states, beginning with New Jersey and Minnesota, then promulgated their own regulations. Dry-cell manufacturers recognized that it was in their own best interest to seize the initiative; otherwise, they might have to deal with 50 sets of rules. NEMA, which includes battery manufacturers among its members, established rules on phasing Hg out of dry

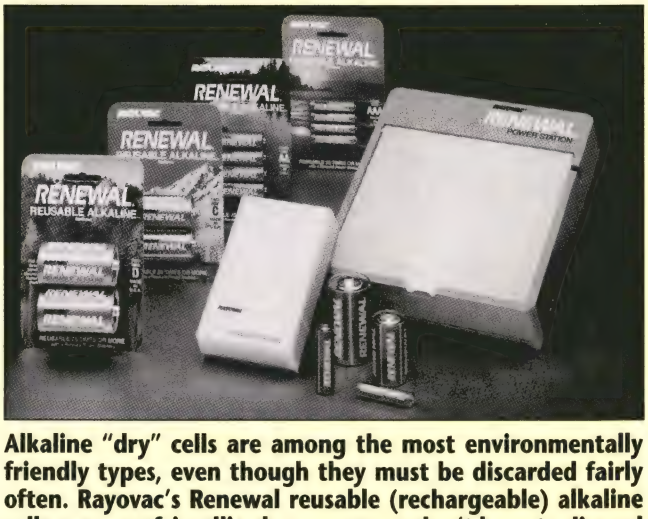
REUSABLE ALKALINE: HELP THE ENVIRONMENT; ASK FOR TROUBLE

Within the past year, Rayovac began selling a battery that it and its competitors had been trying to produce for decades—a practical reusable alkaline cell. (Rayovac's brand name is Renewal.) Because these cells cannot supply high currents as well as NiCd and nickel-metal hydride (NiMH) cells, they are not a general-purpose replacement for the more familiar rechargeable units. However, manufacturers can redesign many products that use NiCd and NiMH batteries to accept reusable alkalines. And reusable alkalines work well in just about every application designed for nonrechargeable alkalines of the same size.

Reusable alkaline batteries *are* friendlier to the environment than the alternatives are. Unlike NiCd, probably the most familiar rechargeable in portable applications, reusable alkalines do not use cadmium or nickel. Unlike NiMH, they do not use nickel or rare-earth metals. Reusable alkalines do even less harm to the environment than do conventional alkaline batteries, with which they have much in common. Although environmentalists consider conventional alkalines safe enough not to require recycling, reusable alkalines are better yet. Because of their rechargeability, they find their way into landfills only a fraction as often.

Despite these advantages, the reusable cells didn't at first receive a warm reception from regulators. The problem was that several states' regulations called for recycling of *rechargeable* batteries, and reusable alkalines are—well—rechargeable. Because the cells are rechargeable, the regulations dictated that users had to recycle them. However, a reusable alkaline that needed to be recycled would be far less attractive than one you could just discard. Without a change in the regulations, Rayovac would not be able to sell as many, there would be fewer economies of scale, and prices would have to rise. That would further reduce the product's appeal...and its environmental benefits.

Rayovac *was* able to work with the regulators to get the rules changed. As a result, you can now buy Renewal cells in AAA, AA, C, and D sizes. A charger that handles four of the AAAs or AAs costs about $15, and Rayovac claims that most users will have paid for the charger by the time they have to replace their first package of four cells. But the story just reinforces what should be painfully clear by now: All too often, environmental regulations are the worst enemy of cleaning up the environment. Moreover, regulators and lawyers whose livelihood depends upon reviewing and changing the regulations have a vested interest in maintaining this status quo. Meanwhile, the taxpayers foot the bill.



Alkaline "dry" cells are among the most environmentally friendly types, even though they must be discarded fairly often. Rayovac's Renewal reusable (rechargeable) alkaline cells are even friendlier because users don't have to discard them as often. Rayovac says that many users will have recovered the cost of the charger (about $15 for the smaller size) by the time their first package of cells needs replacement.

QUICKEST TIME TO MARKET

YOU KNOW QUICKLOGIC® IS THE FASTEST. NOW WE'RE THE EASIEST TO USE.

By using QuickLogic FPGAs, we guarantee your design can be realized faster than ever before.

GUARANTEED ROUTING

QuickLogic has such a wealth of routing resources in every *Wild*Cat™ FPGA that we guarantee utilization of up to 100% of the flipflops and I/O pins. And, with our Quick*Works*™ design tools, it's automatic — placing and routing a complex 4,000 gate design in under 10 minutes.

GUARANTEED PINOUT

With QuickLogic, you can *always* get to that pin. You can lock down your pins and hold them through multiple iterations — even with marketing surprises. No more costly board revisions and schedule slips.

$99 EVALUATION KIT — PUT OUR GUARANTEES TO THE TEST

Want proof with your own design? Call us now and we will send our new Quick*Works* suite of design evaluation tools for just $99.00. If you need more convincing, read on.

GUARANTEED TIMING

With QuickLogic's ViaLink® antifuse technology, logic interconnect impedance is so small that system clock speeds of 100MHz are easily attainable. Our AWE-based delay modeling software guarantees that your device will meet or exceed the reported timing.

GUARANTEED SYNTHESIS QUALITY

Rivaling schematic design entry in device speed and utilization, Quick*Works* introduces the highest quality synthesis for FPGAs. With Quick*Works*' Verilog® and VHDL synthesis (by Synplicity™, Inc.) and OVI-compliant Verilog simulation (by Simucad®, Inc.), quantum leaps in FPGA design productivity can be realized.

Take us up on our guarantee. Call for our tool set and get your design to market quicker. Fax us at **408-987-2012** or call **1-800-842-FPGA**(3742) for a QUICK response.

In *Europe*, call +49 (89) 899 143 28 or Fax +49 (89) 857 77 16.

QUICKLOGIC

We Live Up To Our Name

CIRCLE NO. 185

GREEN BATTERIES

cells, and the industry beat its self-imposed deadlines. Because of the success of the industry initiative, states have refrained from trying to further regulate dry cells' Hg content.

Rechargeable cells and battery packs pose a greater challenge. In electronics, the most common of these are sealed lead-acid and NiCd batteries. Many people regard the relatively new nickel-metal hydride (NiMH) batteries and even newer rechargeable Li batteries as a way around the problems of other types, especially NiCd. In fact, though, no one has yet determined whether to classify NiMH batteries as nonhazardous waste material. Nickel acts as a catalyst in incinerators; to some environmentalists, that's enough reason to classify spent NiMH batteries as hazardous.

Environmentalists are also concerned about lithium, a very active metal. There are many Li battery chemistries. Whereas environmentalists consider batteries that use some of these chemistries safe for disposal in consumer quantities, that is not generally true for industrial quantities. Even in small quantities, it is not the case for Li batteries that contain other toxic materials such as sulfur-dioxide (SO_2). BDT (see **box**, "For free information…") specializes in disposing of Li and other battery types.

Reclamation facilities such as International Metals Reclamation Co (also in the "For free information…" **box**) can recover a greater portion of the metal content of NiCd batteries than of NiMH ones. Thus, as with so many environmental issues, a problem's "obvious" solution (in this case, replacement of NiCd with NiMH) can turn out not to work as well as a seemingly inferior approach (recycling of NiCd cells). The automotive lead-acid-battery industry achieves recycling rates of 95% or more. If the nonautomotive-battery industry can come close to those rates with nickel-containing rechargeable batteries, NiCd batteries will actually do less harm to the environment than the "friendlier" NiMH type.

Even the packaging of batteries is an environmental concern. Regulators—at first, in Europe—may outlaw blister packs because their combination of cardboard and plastic makes them hard to recycle. This replacement, Kodak's"all-card" package, uses no plastic but still allows consumers to see the cells through a cutout.

But therein lies the challenge: establishment of a recycling infrastructure for NiCd, NiMH, and sealed lead-acid batteries used in nonautomotive products—many of them electronic. Establishment of the efficient recycling infrastructure for automotive batteries took decades.

Bureaucracies are us!

Only if you've had some experience dealing with slow-moving and sometimes-inept governmental bureaucracies are you likely to appreciate what the nonautomotive rechargeable-battery industry has gone through to establish a recycling program. Several years ago, manufacturers of NiCd and sealed lead-acid batteries recognized the need to cooperate in addressing environmental issues. That recognition eventually led to the creation of a trade association, the Portable, Rechargeable Battery Association (PRBA).

The PRBA quickly determined that the most practical way to keep battery materials out of the waste stream was a recycling program. It was obvious that, even though recycling might eventually reduce the price of battery raw materials, recycling would initially be costly, and someone would have to pay. If each manufacturer had to establish a separate recycling program, obtaining

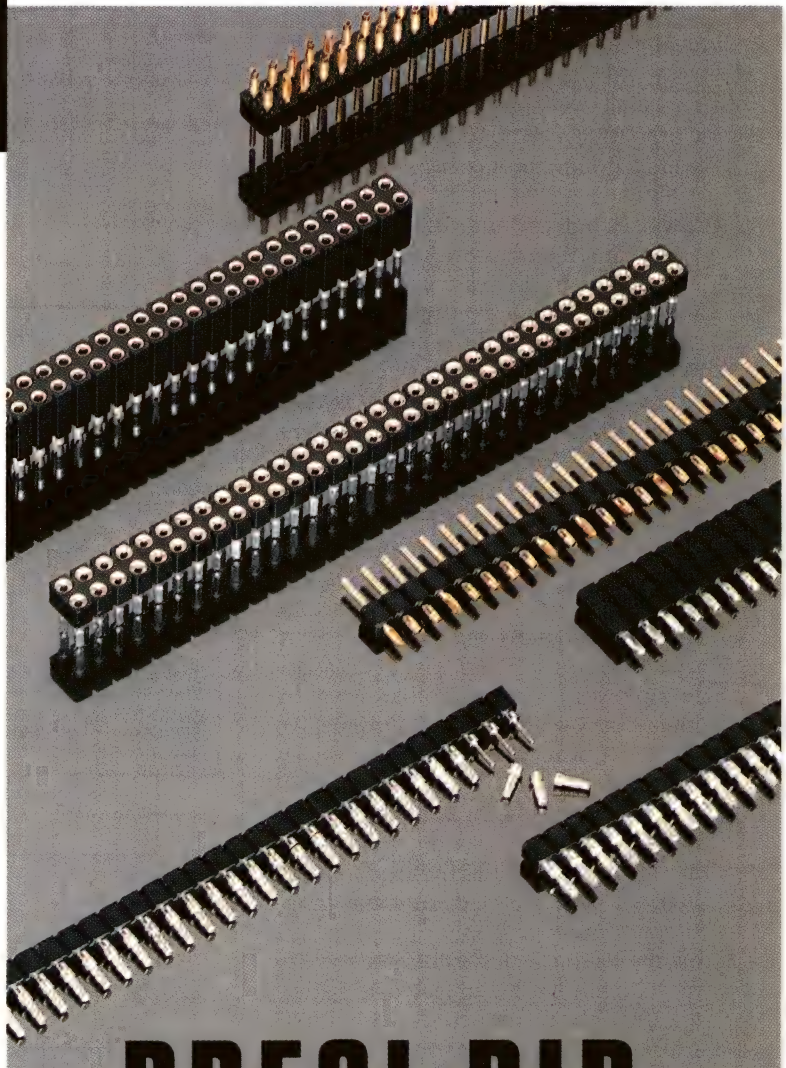
LOOKING AHEAD

Despite their importance to a field as dynamic and rapidly changing as portable electronics, batteries evolve rather slowly. New chemistries don't spring up overnight. Indeed, some in use today have been around for at least a century. Nevertheless, batteries continue to evolve; vendors continually make subtle improvements (removing mercury from dry cells, for example) and not-so-subtle ones (like Rayovac's development of reusable alkaline cells. See **box**, "Reusable alkaline: Help the environment; ask for trouble". Like Eveready's pink Energizer bunny on TV, the vendors keep on going, and going, and going in their quest to make better batteries.

Nevertheless, it would be difficult to predict that over the next year there will be great upheavals in battery technology. Any changes that do occur are unlikely to have a major effect on the environmental friendliness of the batteries used in portable electronic equipment. The most significant development will probably be nontechnical. Expect the Rechargeable Battery Recycling Corp to move its recycling program into high gear and to work out a lot of kinks.

Over the longer term—within the first decade of the 21st century—look for technology developed for automotive batteries to filter down to portable electronics. The results will be batteries—zinc-air, perhaps—that store more energy per gram and per cubic centimeter and that do less harm to the environment than do the batteries we use today.

Need a Top Source for Pressfit Connectors? Call PRECI-DIP.



Imagine how good it would be to know about a perfectly safe way to avoid PCB cracking with densely packed back-panels...

to be able to forget about damaged thruplatings – alltogether with perfect contact safety.

Then, have a look at Preci-Dip's new patented pressfit contact design with the **compliant slotted hollow tail** and fine saw tooth profile to guarantee gas-tight contact zones. A new and better way to say good-bye forever to an old problem.

Another major advantage at the connecting end is Preci-Dip's widely proven contact technology: strong precision machined bodies with the famous, highly reliable, gold plated multi-finger clip. And samples, technical specifications plus pricing readily available. Of course.

Call Preci-Dip or your nearest Preci-Dip dealer for additional info and top service!

Preci-Dip SA
CH-2501 Bienne Switzerland
P.O. Box 396 Phone (32) 251 271
Telecopier (32) 251 270

Staying tough at the top

PRECI-DIP

mecap

IC-Sockets and allied precision products

CIRCLE NO. 69

GREEN BATTERIES

the cooperation of distributors and dealers would be more difficult—maybe impossible. In addition, there would be needless duplication, which would raise costs. Eventually, the PRBA spun off a not-for-profit corporation, the Rechargeable Battery Recycling Corp (RBRC) to manage an industry-wide recycling program.

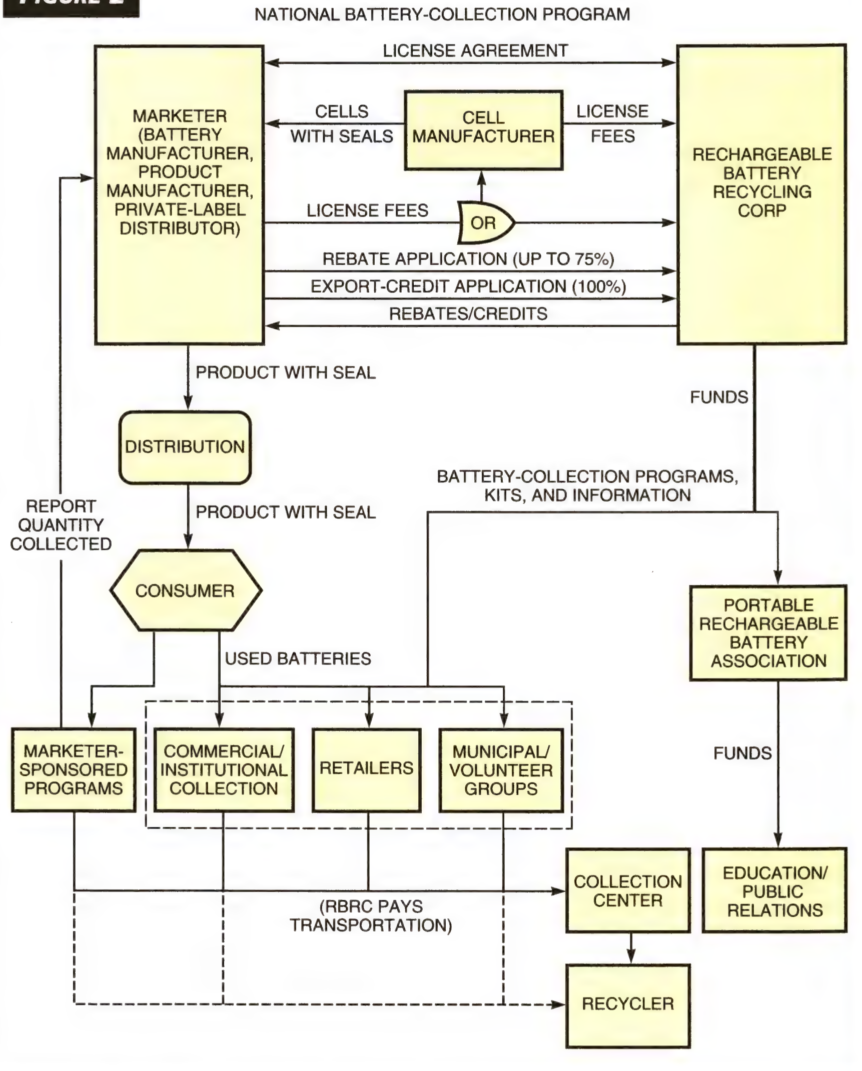
Enter the first roadblock: antitrust laws. If battery manufacturers had agreed among themselves to cover recycling costs by increasing prices, they would have been "conspiring" to raise prices, a violation of the antitrust laws. What evolved was a fairly convoluted licensing system, under which battery manufacturers, distributors, resellers, and manufacturers of equipment that uses batteries, pay royalties to the RBRC for use of its seal. The RBRC bases payments on the weight of the recyclable materials in the products a company ships. In return, the RBRC manages the recycling program (**Fig 2**).

Although the RBRC seal is an adaptation of the by-now-familiar recycling logo, the two differ in significance. An item that bears the "chasing arrows" is made of recycled materials, is itself recyclable, or is both. But the presence of the chasing arrows on a recyclable item isn't sufficient to indicate that the item *must* be recycled. In some cases, though, the logo implies just that. For example, many jurisdictions require recycling of NiCd and lead-acid batteries. Until the introduction of the RBRC seal, however, products that used such batteries carried no indication of this requirement—except for the chasing arrows and a written message.

On a battery, the RBRC seal shows not only that the battery is recyclable, but also that, in many places, it must not be sent to a landfill. The seal also indicates that the supplier participates in the RBRC's industrywide recycling program. So RBRC recycling centers *will* accept the battery. On a product that contains a battery, the RBRC seal signals that the landfills in many areas do not accept the battery, but RBRC recycling centers do accept it.

The next obstacles were rules of the US Environmental Protection Agency (EPA) and its state counterparts. Although intended to encourage recycling, the regulations looked as if they might have the opposite effect. For

FIGURE 2



Keeping the toxic materials in such batteries as NiCd and sealed lead acid out of the waste stream is the objective of the recycling program of the not-for-profit Rechargeable Battery Recycling Corp. Electronic products use a significant fraction of the batteries on which the RBRC focuses.

recycling to work, you must store quantities of the material you will recycle until you have enough of it to transport and process economically. But requirements for complex paperwork make bulk storage and transportation difficult and expensive. The RBRC had to work with regulators to change the rules. (The initial regulations are yet another example of how, if left unchallenged, a way of "solving" an environmental problem can actually make the problem worse.)

One of the biggest handicaps to the smooth operation of the RBRC's recycling program is that recycling and disposal of batteries currently come under the purview of the states. The Resource Conservation and Reclamation Act, a federal law also called the Superfund law, does not set up hard and fast rules. The EPA regulations in this area are advisory only; state laws can preempt them.

Both the US Senate (in Bill No. S.729) and the House of Representatives (in HR.4882) have proposed legislation that would preempt state laws, thereby establishing cohesive national regulations. As this article went to press, the PRBA was encouraging interested parties throughout the industry to urge their senators and representa-

Funny How Time Slips Away.

Except there's nothing funny about clock skew.

As processing speeds increase, clock skew is degrading system performance as never before. Often by as much as 20 percent.

Solution: QSI's new line of logic products that deliver clock signals with guaranteed low skew.

Our value-added QS5244T clock buffer for instance guarantees less skew than the standard FCT244 which it replaces. Plus it reduces skew on wide-address or data buses.

Then there's our low-noise QS5805T/AT family of buffers which give you five outputs for each input — and are available with series termination resistors for even lower noise. You get TTL-compatible inputs and outputs, and QSOP micro-packaging for the tiniest footprint.

A next-generation PLL driver, the QS5917T, recently joined the team. This device achieves zero propagation delay by matching outputs in precise lock step with inputs. And you get better price/performance with a *built-in* loop filter.

All from Quality, the logic company that gave you the fastest CMOS products in the world's smallest packages. For application notes and spec sheets, call 1-800-609-3669. Or Fax 408-496-0773.

Let's share a little Quality time together.

Quality Semiconductor, Inc.

QuickSwitch is a registered trademark of Quality Semiconductor, Inc. Q and QSI are trademarks of Quality Semiconductor, Inc.

CIRCLE NO. 75

GREEN BATTERIES

tives to enact these laws.

The community of people intensely interested in the technical and legal implications of battery recycling is rather small. But considering the large and rapidly growing importance of batteries in electronics, the size of this community has good reason to grow explosively. One way of becoming more knowledgeable is to attend the annual International Seminar on Battery Waste Management. Unfortunately, by the time you read this, the 1994 edition of the seminar will be history. However, the proceedings (as well as those of previous seminars) are available at $95 per copy from Florida Educational Seminars (see **below**). EDN

Reference

1. Small, Charles H, "Batteries explode into new applications and new chemistries," *EDN*, October 13, 1994, pg 63.

You can reach Senior Technical Editor Dan Strassberg at (617) 558-4205, fax (617) 558-4470;
EDN BBS EDNSTRAS
Internet ednstrassberg@mcimail.com

VOTE

Please use the Information Retrieval Service card to rate this article (circle one):

High Interest	Medium Interest	Low Interest
598	599	600

FOR FREE INFORMATION...

For free information on batteries for portable electronic products or on battery disposal and recycling, circle the appropriate numbers on the postage-paid Information Retrieval Service card or use *EDN*'s Express Request service. When you contact any of the following organizations directly, please let them know you read about them in *EDN*. Note that **Ref 1**'s vendor box contains a more complete list of battery suppliers.

BDT Inc
Clarence, NY
(716) 634-6794
Circle No. 301

Duracell Inc
Bethel, CT
(203) 796-4000
Circle No. 302

Eagle Picher
Joplin, MO
(417) 623-8000
Circle No. 303

Eastman Kodak Co
Rochester, NY
(800) 242-2424
Circle No.

Eveready Battery Co
St Louis, MO
(314) 982-2000
Circle No. 304

FDK America Inc
San Jose, CA
(408) 432-8331
Circle No. 305

Florida Educational Seminars
Boca Raton, FL
(407) 338-8727
Circle No. 306

Gould Inc
Eastlake, OH
(800) 722-7890
Circle No. 307

Hawker Energy Products (Successor to Gates Energy Products)
Warrensburg, MO
(816) 429-2165
Circle No. 308

International Metals Reclamation Co (Inmetco)
Ellwood City, PA
(412) 758-5515
Circle No. 309

Maxell Corp of America
Fair Lawn, NJ
(800) 533-2836
Circle No. 310

Minnesota Office of Environmental Assistance
St Paul, MN (612) 296-6300
Circle No. 311

National Electrical Manufacturers Association
Washington, DC (202) 457-8400
Circle No. 312

National Technical Information Service
Springfield, VA
(800) 553-6847
Circle No. 313

Panasonic Industrial Co
Secaucus, NJ
(201) 348-5266
Circle No. 314

Plainview Batteries
Plainview, NY
(516) 249-2873
Circle No. 315

Portable Rechargeable Battery Association
Atlanta, GA
(404) 612-8826
Circle No. 316

Power-Sonic
Redwood City, CA
(415) 364-5001
Circle No. 317

Powercard Corp
Waltham, MA
(617) 890-6789
Circle No. 318

Rayovac Corp
Madison, WI
(608) 275-4692
Circle No. 319

Rechargeable Battery Recycling Corp
Upper Saddle River, NJ
(201) 934-4202
Circle No. 320

SAFT America Inc
Valdosta, GA
(912) 247-2331
Circle No. 321

Sanyo Energy (USA) Corp
San Diego, CA
(619) 661-6620
Circle No. 322

SGS-Thomson Microelectronics
Lincoln, MA
(617) 259-0300
Circle No. 323

Sonnenschein Batteries Inc
Meriden, CT
(800) 437-9348
Circle No. 324

Tadiran Electronic Industries
Port Washington, NY
(516) 621-4980
Circle No. 325

Ultralife Battery Co
Newark, NY
(315) 332-7100
Circle No. 326

US EPA RCRA Superfund Hotline
Arlington, VA
(800) 424-9346
Circle No. 327

US Environmental Protection Agency Solid Waste Division
Washington, DC
(202) 260-5649
Circle No. 328

Varta Batteries Inc
Elmsford, NY
(914) 592-2500
Circle No. 329

Wilson Greatbach Ltd
Clarence, NY (716) 759-6901
Circle No. 330

Yuasa-Exide Inc
Reading, PA
(610) 371-0400
Circle No. 331

Super Circle Number

For more information on the batteries and the recycling, disposal, and educational services provided by all of the vendors listed in this box, you need only circle one number on the postage-paid reader service card.
Circle No. 332

WHAT MAKES THE NEW PowerPC BOARDS FROM MOTOROLA SO FAST?

INTRODUCING THE PowerPC BOARD FAMILY.
Now Motorola's leading-edge board technology brings you leading-edge PowerPC™ boards. These new boards will speed up your product development, your system performance, and more than likely, your heartbeat.

DESIGNED TO SHRINK YOUR DESIGN TIME.
Slice weeks or even months off your product development time. Our PowerPC boards are ready today, so you can get right to work on your systems. Development software is also ready to go. Right now.

A WARRANTY AS AMAZING AS THE BOARD.
Developing this fast has never been this safe. All of our PowerPC boards are backed by the industry's first Five-Year Warranty. Call today for complete information about our PowerPC boards.

FIVE - YEAR
MOTOROLA COMPUTER GROUP
5
WARRANTY

Available in VME and Non-VME Platforms. Ethernet and SCSI-2 Interfaces. SVGA Graphics. Low Profile Desktop Form Factors. 66 MHz PowerPC 603. 100 MHz PowerPC 604. Parallel and Serial I/O. Floppy and IDE Interfaces. 8 to 128MB DRAM. 33 MHz PCI Local Bus with PCI and ISA Expansion Slots. PowerPC Reference Platform Compatible. Development Software Available for PowerPC Reference Platform Compatible Software Environments.

CIRCLE NO. 155

MOTOROLA
Your Source *for* **POWER** Computing™

Australia	Belgium	China (PRC)	France	Germany	Hong Kong	Italy	Japan	Korea	Netherlands	Scandinavia	Spain	Taiwan	UK
61-2-906-3855	32-2-718-5582	86-1-843-7222	33-1-4674-3560	49-40-236204-0	852-966-3210	39-2-8220-239	81-3-3280-8461	82-2-720-0653	31-30-870857	46-8-734-8800	34-1-329-0461	886-2-717-7089	44-628-39121


BERG™ GIVES YOU MORE THA
MORE DESIGN OPTIONS, MORE COMPLETE CONNECTO
CONAN™
MICROMINIATURE 1.0mm
METRAL™
THE FUTUREBUS+ STANDARD 2.0m
MICROPAX™
HIGH-SPEED HIGH DENSITY 0.64mm
HARBOR ELECTRONICS
CABLE ASSEMBLIES
MOLDCON AND
TRI-TECH ENGINEERING
CABLE ASSEMBLIES
McKENZIE TECHNOLOGY
BERG
ELECTRONICS
CERTIFIED ISO 9001


VER. . . WHEREVER, WHENEVER.
STEMS, MORE DESIGN / MANUFACTURING LOCATIONS.
RIBCAGE™ II
LOW-PROFILE 1.27mm
HPC (HIGH PIN COUNT)
HIGH DENSITY SYSTEM
BERG
MORY CARD SYSTEMS
E FIRST, THE MOST, THE LATEST.
MAC II™ FIBER-OPTIC CONNECTOR SYSTEMS (FORMALLY AT&T CONNECTOR SYSTEMS)
SOCKET EXPRESS
Today, Berg's accelerating growth, from both our core operation and strategic acquisitions, enables us to offer you a worldwide connector service second to none. And the only one that meets the ISO 9001 Standard, worldwide. Our expanded product line will fill your connector needs from "A to Z". Berg can supply complete connector assemblies—connector, cable and socket—sourced internally, 100%. Results: compatibility of components; precise performance and controlled quality. Also, with our extensive design and laboratory facilities, Berg can co-develop your next connector design with you, to meet or exceed your expectations for signal integrity, miniaturization, speed and electrical and mechanical requirements. Berg's worldwide design/manufacturing network lets us produce your design at a location within reach of your delivery destination—just one factor enabling us to reduce your time to market. For a visual presentation of how Berg's worldwide capabilities can dovetail with your needs, send for our new brochure, "The Fast Lane To Market."
CALL US ANYWHERE IN THE WORLD YOU CHOOSE TO WORK.
HERTOGENBOSCH, NETHERLANDS: Phone: + 31 73 206 504; FAX: + 31 73 214 439 • LES ULIS CEDEX, FRANCE: Phone: + 33 1 69 188 890; FAX: + 33 1 69 299 758 • OBERURSEL, GERMANY: Phone: + 49 61 715 8840; FAX: + 49 61 715 88444 • HITCHIN HERTS, UNITED KINGDOM: Phone: + 44 462 44 1555; FAX: + 44 462 441 600 • TOKYO, JAPAN: Phone: + 81 3 5493 5200; FAX: + 81 3 5493 5233 • KYUNGGI-DO, KOREA: Phone: + 82 336 301265; FAX: + 82 336 301117 • NGEE ANN CITY, SINGAPORE: Phone: + 65 738 8277; FAX: + 65 738 4122 • KOWLOON, HONG KONG: Phone: + 852 721 2220; FAX: + 852 723 0787 • TAOYUAN, TAIWAN: Phone: + 886 3 454 9173; FAX: + 886 3 462 0676 • MADURAI, INDIA: Phone: + 91 11 5734027; FAX: + 91 11 5755738 • MISSISSAUGA, CANADA: Phone: 905 826 9810; FAX: 905 826 1477 • ETTERS, PA, USA: Phone: 717 938 6711; FAX: 717 938 7604.
CIRCLE NO. 116

GETTING GREEN PC BOARDS BECOMES A BURNING ISSUE

BRIAN KERRIDGE, SENIOR TECHNICAL EDITOR

Constituents of today's pc-board material limit flammability but exude evil gases when burning. Tomorrow's pc-board material burns cleanly and is well ahead of controlling legislation.

If you happen to fall asleep while reading this article, and if the furniture you're resting on happens to catch fire, chances are you'll survive the incident. But nod off near a smoldering rack of pc cards, and that's where the story will end. For, although Western legislation has long since outlawed furniture materials that burn with toxic fumes, electronic products still burn with damaging effects, and similar regulations have yet to apply.

In 1989, Siemens Corporate Research and Development, based in Erlangen, Germany, embarked on a project to study this burning problem and to develop replacement materials. The result of the company's work is a patented pc-board material, called FRN, which not only burns "greenly" but also will be in products in 1995 and looks set to replace today's widespread use of FR4 material.

Although you may not regard electronic products as generally combustible, they increasingly intermingle with flammable objects in our offices, factories, and homes. Evidence shows that twice as many deaths occur due to a fire's toxic emissions than directly from the flames, and so the threat of injury from burning electronic products is very real. Within electronic products, burning pc-board material causes the major environmental impact, although the effects of burning component encapsulation and IC plastic packaging are also significant. Currently, the annual worldwide volume of electronic products contains around 350,000 tonnes of pc-board material and 100,000 tonnes of molding compounds (1 tonne=1000 kg).

These noxious emissions will take on greater environmental relevance as countries introduce stringent recycling and waste-disposal regulations. Limiting the spread of dangerous compounds during recycling and disposing of waste by incineration will become commonplace requirements. Ultimately, part of that legislation will enforce you to control the environmental impact of your designs, which means

GREEN PC BOARDS

you'll need to consider factors affecting product destruction alongside your work on product creation (see **box**, "Adopting a life-cycle design mentality").

Flame-retardants kick up stink

Ironically, substances originally designed-in to pc boards and component encapsulants as flame-retardants are the very same substances at the source of the noxious emissions problem. Plastic materials are generally flame-retardant according to Underwriters Laboratories specification UL 94V-0. This specification requires that flames should extinguish less than 5 sec after you subject the material to a 10-sec burn.

Traditionally, substances designed-in to meet this specification come from the halogen group of elements, of which bromine or chlorine is a common choice. For example, regular FR4 pc-board material contains around 10% bromine compounds.

When pc-board material burns, these bromine compounds release hydrogen bromide and bromine radicals, which quench the fire by inhibiting a chain reaction with oxygen. Humans and the environment suffer because hydrogen bromide and bromine radicals are extremely corrosive and because burning generates highly toxic gases—dibenzodioxins and dibenzofuranes.

As a further twist, component-encapsulating material contains antimony trioxide as a synergist to bond bromine compounds into the chemical structure of the material. When burning, components disperse antimony-trioxide dust, which is carcinogenic.

Siemens' work in developing replacement plastics has focused on eliminating all traces of halogen and antimony trioxide while preserving structural, electrical, and processing characteristics and also retaining flame-retardancy.

For the new FRN pc-board material, Siemens uses nitrogen and phosphorous compounds to achieve flame-retardancy. These compounds have a high affinity to combine with oxygen, leaving less oxygen to sustain combustion. In fact, phosphorous compounds, in particular, further assist flame-retardancy by forming a smooth vitreous heat-insulating cocoon over the surfaces of a burning pc board. To comply with UL 94V-0, FRN material contains around 2.7% phosphorus. Burning tests at the German Research Center for Health and the Environment in Neuherberg and at the University of Bayreuth show no evidence of the release of phosphorus compounds into the atmosphere.

To add momentum to the introduction of FRN material, Siemens has enlisted the aid of other German companies, such as chemical giants Bayer and Hoechst and laminator Isola. Sample material from these companies has passed

Table 1—Comparison of green FRN, typical FR4 pc-board material (1.6 mm), and MIL-P-13949G

Property	FRN	FR4	MIL-P-13949G
Surface resistivity (Ω) (23°C)	4×10^{11}	4×10^{12}	10^{10}
(150°C)	1.5×10^{13}	7×10^{10}	10^{9}
Volume resistivity (Ω.cm) (23°C)	4.9×10^{11}	8×10^{14}	5×10^{11}
(150°C)	5.4×10^{11}	8×10^{11}	10^{9}
Dielectric constant	4.66	4.70	5.40
Dielectric loss factor (tan δ)	0.012	0.019	0.030
Water absorption	0.33%	0.15%	0.35%
Glass transition temperature	195°C	135°C	Unspecified
Copper peel strength (35 μm)	1.7N/mm	2.0N/mm	1.4N/mm

LOOKING AHEAD

Increasingly, the principle of "producer responsibility" for the environmental impact of products will penetrate the tranquility of your design office.

To engender that principle, government authorities such as the Environmental Protection Agency in the United States and the Industry Council for Electronic Equipment Recycling in the United Kingdom are preparing the way for controlling legislation. The form of the legislation is as yet unclear, but in the European Community, proposals to impose a "disposal levy" on producers is one possibility. Nasty products will attract high levies; friendly products may escape totally.

Germany is Europe's greening force, and the principle of producer responsibility is already evident there. Buyers increasingly demand that vendors take back old products when they buy anew. Germany also expects to be first with legislation (within three years), and the German auto industry already places environmental requirements on its suppliers.

In anticipation of these moves, companies are busy developing internal environmental-design policies. Siemens, for example, has implemented wide-ranging internal guidelines. As part of the program, Siemens classified the range of plastics used throughout its products into five categories ranging from "highly recommended" to "do not use." The program requires designers to seek formal levels of approval to use parts containing plastics in the various categories and will phase out some categories altogether.

Eliminating halogen flame-retardants in pc-boards and discrete component encapsulants was a necessary part of the program, and you can expect Siemens to report similar progress on IC plastic packaging by the end of 1995.

To assist you in operating your own policies, companies will increasingly state the environmental impact of products, maybe through a system of labeling. Companies such as National Semiconductor, Philips Semiconductors (**Ref 2**), and Siemens already routinely publish data specifying the chemical content of their products.

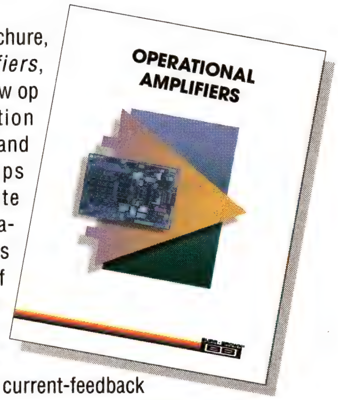
New Product Update

CSI Termination Chip with Power-Down Mode

G5601 is an 18-line active terminator for SCSI–2 circuitry. On-chip resistors and 2.9V regulator ovide the prescribed 110Ω termination for low power dissipation and high speed data transmission. an alternate source for the popular "5601" SCSI terminator. All line connections can be disconnected m the bus with a single logic control line to reduce standby power consumption. Key specs lude: 2.9V current-limited and thermally protected regulator, power-down mode of 150µA max, d an output capacitance in disconnect mode of 10pF typ. REG5601 is packaged in a 28-lead surface ount package.

CIRCLE NO. 26

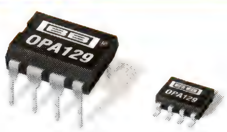
New *Operational Amplifiers* Brochure



A new eight-page brochure, *Operational Amplifiers*, features over twenty new op amps. It has selection guides on precision and high speed op amps along with complete descriptions, specifications, and applications info. Four pages of technical info highlight high speed amps, video amps, audio amps, precision amps, current-feedback amps, wide bandwidth amps, single power supply amps, precision FET amps, and switchable-input amps. Available from local sales representative.

CIRCLE NO. 27

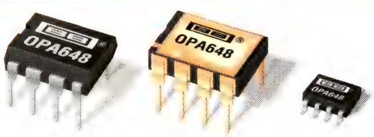
New



lectrometer-Grade Op Amp 1 8-pin DIP and SO-8

PA129 is an electrometer-grade op amp fered in cost-saving 8-pin DIP and SO-8 ırface-mount packages. Its 100fA max input as current makes it ideal for high impedance ensors, low drift integrators, pH probe ampli-ers, and ion gauge measurement. Its innovative nout preserves its low bias current by allowing oom for circuit board guard traces—even with e tiny SO-8 package. Key specs are: 100fA ax bias current, 2mV max offset voltage, 0µV/°C max drift, and 15nV/√Hz at 10kHz noise.

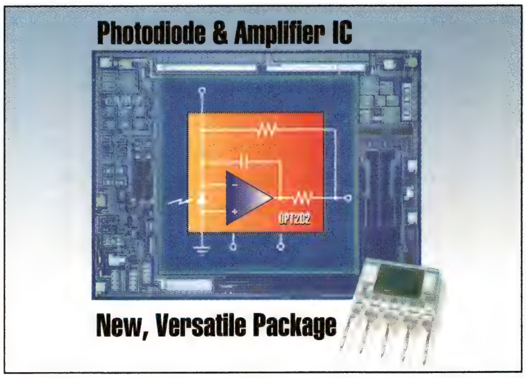
CIRCLE NO. 28



World's Fastest Current Feedback Op Amp—1GHz

OPA648 is a high speed current feedback op amp with 1GHz unity-gain bandwidth—perfect for today's demanding video, medical imaging, and test/analytical instrumentation applications. It achieves this high bandwidth while dissipating only 13mA of quiescent current. Key specs are: 20ns settling time, 1200V/µs slew rate, 0.02%/0.02° differential gain/phase, and a 9dB noise figure. OPA648 operates from ±5V supplies and is offered in 8-pin plastic DIP, SOIC and hermetic ceramic packages.

CIRCLE NO. 29



New Photodiode/Amplifier IC in "Optically Friendly" Package

OPT202 is now available in an innovative package—a new 5-pin SIP that mounts vertically for light sources entering the edge of a circuit board. It's ideal for many industrial applications including medical and laboratory instrumentation, position and proximity sensors, photographic analyzers, and smoke detectors. Key specs are: 1MΩ feedback resistor, 2mV dark errors, 0.45A/W (650nm) responsivity, 400µA quiescent current, 0.05% nonlinearity, and ±2.25 to ±18V supply range.

CIRCLE NO. 30

New

±2A, ±35V Dual Power Operational Amplifier

)PA2544 is a dual, high-voltage, high-current operational amplifier suitable for driving high power loads. It packs two powerful amps in a single TO-3 package—saving ›oard space and money. It provides output of up to 2A and its power supply range extends to ±35V. It's also ideal for programmable power supplies and automatic test quipment. Key specs are: 2A output current, 8V/µs slew rate, 50pA input bias current, internal current limit, and internal thermal shutdown protection. Available in an 3-pin metal hermetic TO-3 package.

CIRCLE NO. 31

GREEN PC BOARDS

through established pc-board processes and has been compared in detail with FR4 and the internationally accepted standard MIL-P-13949G (**Table 1**). Siemens has constructed a range of prototype pc-board assemblies and will introduce FRN material to its own electronic assembly lines during 1995.

Secondary savings tip balance

Naturally, the cost of FRN is a major concern, but according to Dr Wolfgang Rogler, thermosetting materials manager at Siemens, the overall penalty is not so severe. Rogler says that, most important, FRN is entirely compatible with established pc-board processes and equipment and involves users in no additional capital expense. The board material is around 10 to 20% more expensive than today's halogen-based alternative. Although the material is in full-scale production, this increase translates to less than 1% on a typical pc-board assembly.

Rogler says it's important for industry to recognize secondary cost savings that redress the balance. For example, pc-board production traditionally involves high levels of material waste due to cropping—up to 30%. The absence of halogens now opens up the prospect of recycling these waste products.

Also, the absence of corrosive and toxic effects dramatically reduces fire damage to surrounding equipment and the environment, leading to lower cleanup costs and, in turn, to lower insurance premiums.

FRN also has a higher glass transition temperature than FR4 and therefore exhibits greater structural stability at higher temperatures. This feature enables faster production using higher temperature flow soldering or implies fewer rejects due to board distortion at normal solder temperature. Greater stability also opens up the possibility of applications using thinner pc boards.

In the longer term, industry will have no choice but to follow a path to increasingly tighter environmental regulations. Eliminating halogens will be seen as a necessary step along that path—and one well worth paying for to secure a new level of environmental safety from electronic products. EDN

ADOPTING A LIFE-CYCLE DESIGN MENTALITY

Creating products is a responsibility you accept with enthusiasm and relish. Destroying those same products is a responsibility you don't expect to carry and one you currently disregard.

Quite soon, though, that situation will change. You'll become just as responsible for your product's destruction as you now are for its creation. You will adopt a life-cycle design mentality **(Ref 1)**. Your aim will be to minimize the environmental impact of a design throughout its life—and during its eventual destruction. To do this, you'll need to design with components and materials and employ processes, such as easy disassembly, that prevent pollution and aid recycling. Eventually, your success in achieving these aims will become yet another measure of your product's quality.

FOR FREE INFORMATION...

For free information on the materials and environmental issues discussed in this article, circle the appropriate numbers on the postage-paid Information Retrieval Service card or use *EDN*'s Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in *EDN*.

Bayer
Leverkusen, Germany
(214) 3081725
Circle No. 357

Hoechst
Frankfurt, Germany
(69) 3050
Circle No. 358

Industry Council for Electronic Equipment Recycling
London, UK
(71) 729 4766
Circle No. 359

Isola
Düeren, Germany
(2421) 8080
Circle No. 360

Philips Semiconductors
Eindhoven, The Netherlands
(40) 722091
Circle No. 361

National Semiconductor
Fürstenfeldbruck, Germany
(81) 41103349
Circle No. 362

Siemens
Munich, Germany
(89) 63647058
Circle No. 363

US Environmental Protection Agency
Cincinnati, OH
(513) 569-7931
Circle No. 364

Super Circle Number
For more information on materials and environmental products available from all of the vendors listed in this box, you need only circle one number on the postage-paid reader service card.
Circle No. 365

References

1. US Environmental Protection Agency, "Life Cycle Design Guidance Manual," EPA/600/R-92/226, January 1993.

2. Philips Semiconductors, "Chemical content of semiconductor devices," 1993/94.

You can reach Senior Technical Editor Brian Kerridge in the UK at (508) 528435, fax (508) 528430.

VOTE

Please use the Information Retrieval Service card to rate this article (circle one):

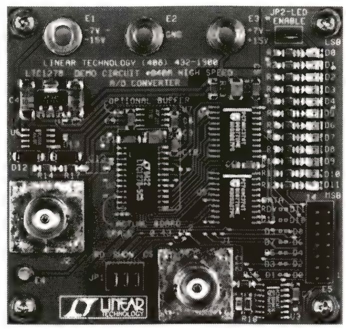
High Interest	Medium Interest	Low Interest
583	584	585

LINEAR TECHNOLOGY

Linear Solutions
A/D Converters

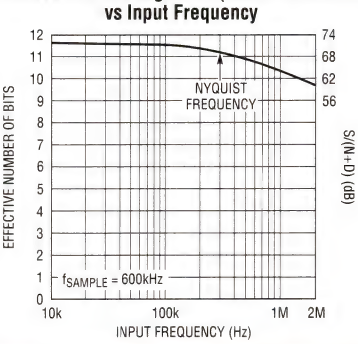
Complete 12-Bit ADC Operates on Single 5V Supply at 600ksps

The LTC1279 is a high speed sampling ADC designed for demanding telecom and signal analysis applications. It has true 12-bit performance from DC to Nyquist.



Key Features are:

- 600ksps throughput
- 70dB S/(N+D) at Nyquist
- 60mW power dissipation and shutdown
- Complete ADC in small footprint
- Single 5V or ±5V supply



LTC1279
Effective Bits and Signal-to-(Noise+Distortion) vs Input Frequency

The LTC1279 contains a sample-and-hold, synchronized conversion clock, precision voltage reference and high speed, parallel interface to DSP and microprocessor ports. The LTC1279 also features an 8.5mW powerdown mode with instant wake-up for additional power savings and is available in narrow 24-pin DIP and SO packages.

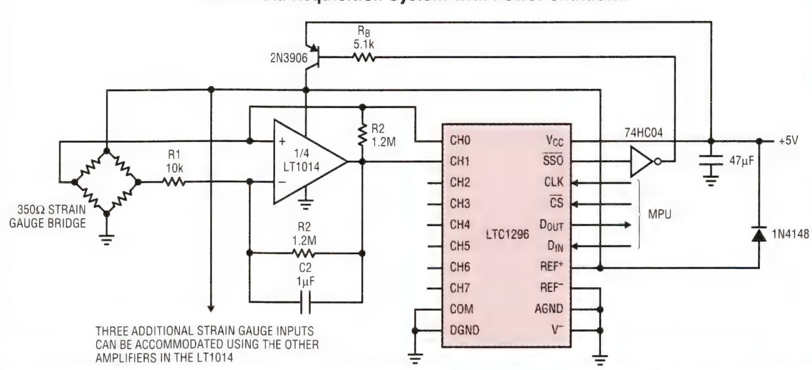
Single Supply 8-Channel 12-Bit ADCs Have 10μA Shutdown

The LTC1296 is a 46ksps ADC designed to fit a wide variety of industrial process control equipment and multiplexed data acquisition systems.

Included on-chip are:

- Software programmable, 8-channel multiplexer
- Precision sample-and-hold
- Power shutdown mode with status pin
- Single 5V or ±5V supply operation

LTC1296
12-Bit Data Acquisition System with Power Shutdown



The multiplexer can be programmed for 8 single-ended or 4 differential inputs or combinations of both. The 3-wire serial interface is compatible with Microwire™, SPI and QSPI, and facilitates remote monitoring and isolated applications. Available in 20-pin DIP and SO packages. Pricing begins at $8.23 in 1000-piece quantities, for 20-pin DIP.

Microwire is a trademark of National Semiconductor Corporation

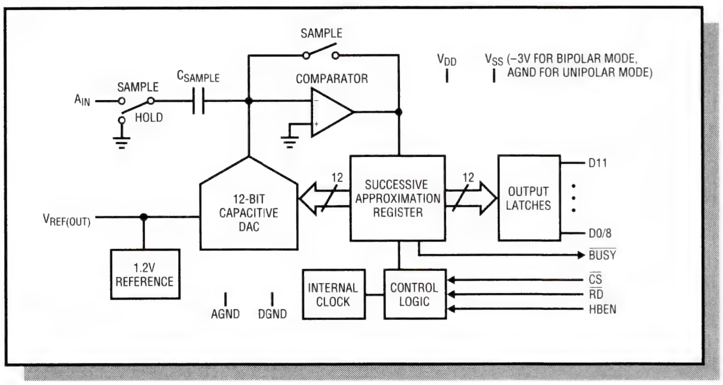
Complete High Speed 3V 12-Bit ADC for Portable Data Acquisition

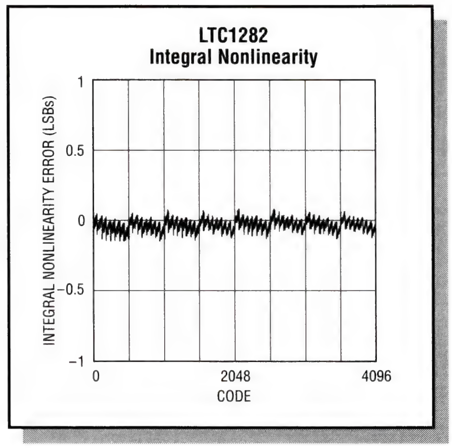
Operating at 140ksps, the LTC1282 is a complete, high speed 12-bit ADC for 3V and ±3V supply applications that dissipates only 12mW. No missing codes and a ±1/2 LSB max INL combine to offer true 12-bit performance in a complete package. Dynamic performance is an outstanding 69dB S/(N+D) at Nyquist.

The LTC1282 comes complete with:

- Sample-and-hold
- Precision 25ppm/°C voltage reference
- Easy to use, high speed parallel interface

Packaged in 24-pin DIP and SO, the LTC1282 fits a wide variety of portable and battery-powered applications including audio, spectrum analysis and telecommunications processing. Pricing for the LTC1282 begins at $13.47 in 1000-piece quantities.

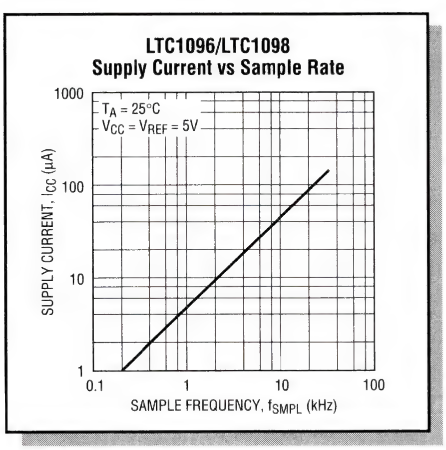


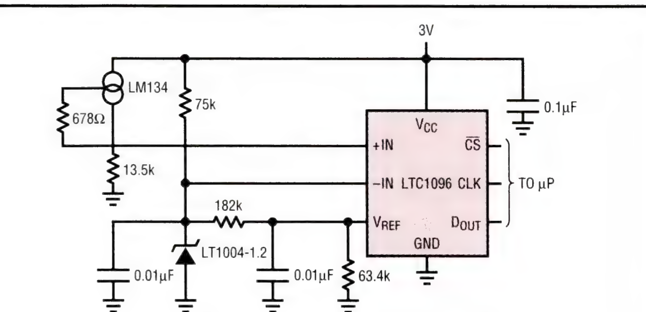


Low Cost 8-Pin SOIC, 8-Bit ADCs Auto-Shutdown to 1nA Supply Current

The LTC1096/LTC1098 are low cost 8-bit ADCs in 8-pin DIP and SO packages that operate from a single 3V to 9V supply. Operating current is a low 180μA max, and the devices automatically power down to 1nA between conversions, further increasing power savings. The 3-wire serial I/O is Microwire, SPI and QSPI compatible and easily adapts to remote and isolated data acquisition.

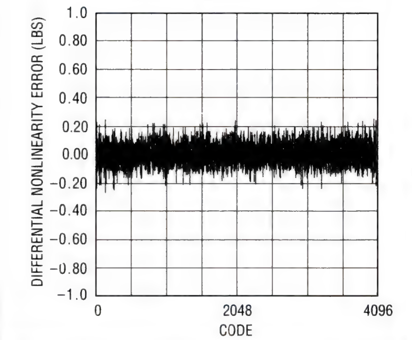
The LTC1098 input has 2-channels while the LTC1096 features a differential input. Small size and low cost ($2.82 in 1000-piece quantities) make the LTC1096/LTC1098 ideal for space conscious, power sensitive applications such as RSSI (Receive Signal Strength Indicator), battery monitoring and touch screen interface.





THE LTC1096's HIGH IMPEDANCE INPUT CONNECTS DIRECTLY TO THIS TEMPERATURE SENSOR, ELIMINATING SIGNAL CONDITIONING CIRCUITRY IN THIS 0°C to 70°C THERMOMETER

Micropower 12-Bit ADCs in SO-8 for Battery and Portable Systems

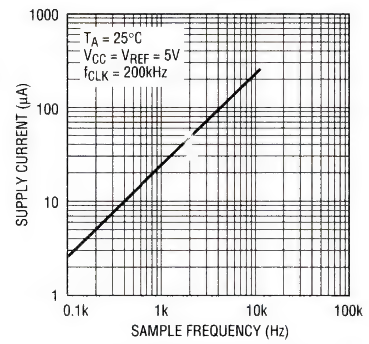


LTC1286/LTC1298
Differential Nonlinearity vs Code

The LTC1286/LTC1298 are tiny 12-bit ADCs that draw 250µA from a single 5V supply when converting and automatically power down to 1nA between conversions. Packaged in 8-pin DIP and SOIC, the LTC1286 features a differential input while the LTC1298 input has 2 channels. Both devices have Microwire, SPI and QSPI compatible serial interfaces and easily accommodate isolated applications.

The LTC1285 and LTC1288 are pin compatible versions designed and specified for 3V supply applications.

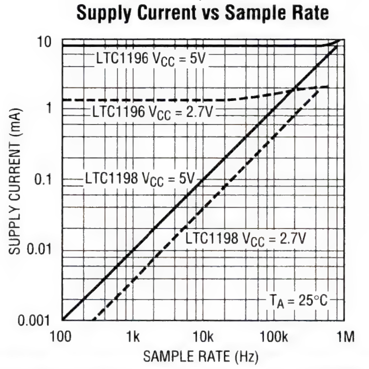
Pricing begins at $4.65 in 1000-piece quantities, perfect for high volume, space and power sensitive applications such as pen screen interface, remote data acquisition and battery monitoring and battery-powered portable instruments.



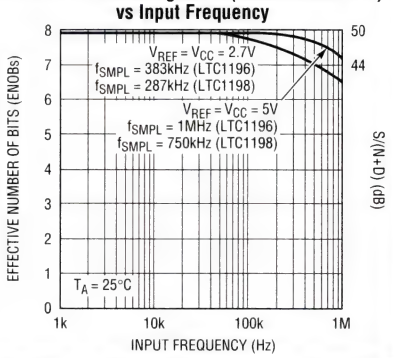
LTC1286/LTC1298
Supply Current vs Sample Rate

1MHz 8-Bit ADCs in SO-8 Save Power and Space

The LTC1196/LTC1198 are fast 8-bit ADCs that operate from a 3V or 5V single supply and convert 1MHz inputs to 7 Effective Bits. The LTC1196 has a differential input, and the 2-channel multiplexed LTC1198 automatically powers down to 1nA between conversions. Both devices are available in SO-8 packages and provide high speed 3-wire serial I/Os for RSSI, bar-code scanners and portable DSP. Low power (7mA typ), low cost ($2.37 in 1000-piece quantities) and excellent dynamics make the LTC1196/LTC1198 ideal for demanding high frequency, power sensitive applications.



LTC1196/LTC1198
Supply Current vs Sample Rate



LTC1196/LTC1198
Effective Bits and Signal-to-(Noise+Distortion) vs Input Frequency


Actual Size

Sampling A/D Converters

Part	Resolution (Bits)	F_{SAMPLE} (ksps Max)	# of Inputs	V_{REF}	Data* I/O	V_{CC} (V)	P_{DISS}** (mW)	Features	Package†
LTC1096	8	33	1	Ext	Serial	2.7-9	0.6/0	Micropower SO-8 ADC	N8/S8
LTC1098	8	33	2	Ext	Serial	2.7-6	0.6/0	2-Channel LTC1096	N8/S8
LTC1196	8	1000	1	Ext	Serial	2.7-6	55	1Msps SO-8 ADC	N8/S8
LTC1198	8	750	2	Ext	Serial	2.7-6	55/0	2-Channel LTC1196	N8/S8
LTC1090	10	30	8	Ext	Serial	4-9	5	Low Power Multiplexed ADC	N20/S20
LTC1091	10	31	2	Ext	Serial	4-9	7.5	8-Pin 2-Channel ADC	N8
LTC1092	10	38	1	Ext	Serial	4-9	5	8-Pin 10-Bit ADC	N8
LTC1093	10	26	6	Ext	Serial	4-9	5	Low Power Multiplexed ADC	N16/S16
LTC1094	10	26	8	Ext	Serial	4-9	5	Low Power Multiplexed ADC	N20
LTC1095	10	26	6	+5.0	Serial	4-9	15	Complete 6-Channel ADC	N18
LTC1283	10	15	8	Ext	Serial	3-3.6	0.45	3V LTC1090	N20
LTC1286	12	12.5	1	Ext	Serial	4-9	1.25/0	Micropower SO-8 12-Bit ADC	N8/S8
LTC1298	12	11.1	2	Ext	Serial	4-6	1.7/0	2-Channel LTC1286	N8/S8
LTC1290	12	50	8	Ext	Serial	4-6	30/0.05	8-Channel ADC	N20/S20
LTC1291	12	54	2	Ext	Serial	4-6	30/0.05	8-Pin 2-Channel ADC	N8
LTC1292	12	60	1	Ext	Serial	4-6	30	8-Pin 12-Bit ADC	N8
LTC1293	12	46	6	Ext	Serial	4-6	30/0.05	6-Channel ADC	N16
LTC1294	12	46	8	Ext	Serial	4-6	30/0.05	8-Channel ADC	N20/S20
LTC1296	12	46	8	Ext	Serial	4-6	30/0.05	LTC1294 w/Shutdown Output	N20/S20
LTC1297	12	50	1	Ext	Serial	4-6	30/0.05	LTC1292 w/Auto-Shutdown	N8
LTC1285	12	7.5	1	Ext	Serial	2.7-6	0.48/0	3V LTC1286	N8/S8
LTC1288	12	6.6	2	Ext	Serial	2.7-6	0.63/0	3V LTC1298	N8/S8
LTC1287	12	30	1	Ext	Serial	2.7-6	3	3V LTC1292	N8
LTC1289	12	25	8	Ext	Serial	2.7-6	3/0.03	3V LTC1290	N20/S20
LTC1272-8	12	100	1	2.42	µP 8 or 12	+5	75	Sampling AD7572-12	N24/S24
LTC1272-3	12	250	1	2.42	µP 8 or 12	+5	75	Sampling AD7572 A-3	N24/S24
LTC1273	12	300	1	2.42	µP 8 or 12	+5	75	5V High Speed ADC w/Ref	N24/S24
LTC1275	12	300	1	2.42	µP 8 or 12	±5	75	High Speed ADC w/Ref	N24/S24
LTC1276	12	300	1	2.42	µP 8 or 12	±5	75	High Speed ADC w/Ref	N24/S24
LTC1278-4	12	400	1	2.42	µP 12	5/±5	75/5	Sampling ADC w/Shutdown	N24/S24
LTC1278-5	12	500	1	2.42	µP 12	5/±5	75/5	Sampling ADC w/Shutdown	N24/S24
LTC1279	12	600	1	2.42	µP 12	5/±5	75/5	Sampling ADC w/Shutdown	N24/S24
LTC1282	12	140	1	1.20	µP 8 or 12	3/±3	12	3V Sampling ADC	N24/S24

* Serial I/O is Microwire, SPI and QSPI compatible
** Power dissipation is listed in the Active and Shutdown modes
† N8 = 8-pin DIP S8 = 8-pin SOIC
N16 = 16-pin DIP S16 = 16-pin SOIC
N18 = 18-pin DIP S20 = 20-pin SOIC
N20 = 20-pin DIP S24 = 24-pin SOIC
N24 = 24-pin DIP

LINEAR TECHNOLOGY

Linear Technology Corporation
1630 McCarthy Blvd.
Milpitas, CA 95035-7487
Phone: (408) 432-1900
Fax: (408) 434-0507
For literature only: **1-800-4-LINEAR**

CIRCLE NO. 87

Sampling new performance-boosting GUI chip 3rd Quarter 1994.

50ns shipments beginning 2nd Quarter 1994.

Sampled 1st Quarter 1993.

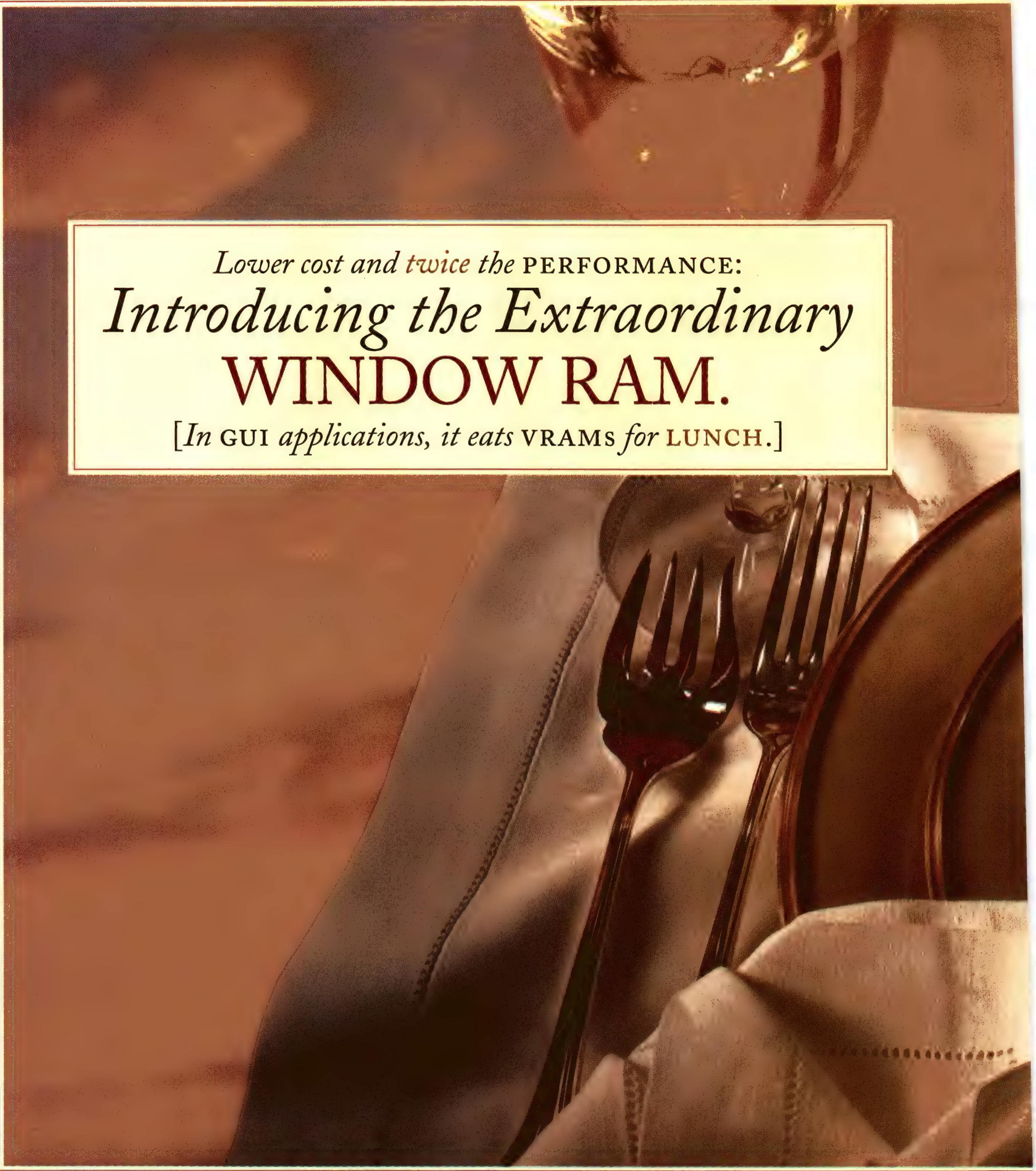
Worldwide sales leader in MOS memory for 1993, as cited by Dataquest Inc.

Delivered to customers in volume 3rd Quarter 1991.

100Mhz shipments beginning 3rd Quarter 1992.

Samsung's performance in the memory race has been rather spectacular of late. Which, for our customers, is a very good thing. Because it makes for geographic diversification in supply. And it means there's a major source truly committed to the U.S. market. Since completing the first 16-meg DRAM, we've gone on to become the No. 1 memory supplier worldwide. Based on DRAMs but also on SRAMs, VRAMs, Flash, ROMs, and emerging memory categories. To achieve this, we spend some 15% of revenues on R&D. And we're being awarded patents at a rate of hundreds per year. We plan on continuing our winning ways. Which, in turn, means you win too.

SAMSUNG
SEMICONDUCTOR
A *Generation* AHEAD.
CIRCLE NO. 188



Lower cost and twice the PERFORMANCE:

Introducing the Extraordinary WINDOW RAM.

[*In* GUI *applications, it eats* VRAMS *for* LUNCH.]

Nowadays, graphical user interfaces are everywhere. But they're also terribly slow.

We at Samsung decided it was time somebody fixed that.

Which is why we've designed a new product—with a new architecture—that not only outperforms VRAMs* but sells for much less.

The 8-Mbit Window RAM gives you a 1024 x 1024 x 8-bit frame buffer.

Its 20 ns extended data out Fast Page Mode will give you a minimum of 33% more speed than the fastest VRAMs. And the Window RAM incorporates several dedicated GUI-accelerating features. All of which means that— yes—it eats VRAMs for lunch.

You'll find that the Window RAM's familiar interface makes designing with it easy. And you'll also find that a new generation of graphics controllers will support it. So you'll not only be able to put the Window

*SURPASSES VRAMS IN PERFORMANCE BY UP TO 180% IN BENCHMARKS. © SAMSUNG SEMICONDUCTOR, INC., 1994.

EDITED BY CHARLES H SMALL & ANNE WATSON SWAGER

Digital tachometer avoids analog vices

TAN VAN NGUYEN, IBM SSD DIVISION, SAN JOSE, CA

The digital tachometer in **Fig 1a** is a component of the digital seek servo loop in **Fig 1b**. The loop produces an error signal that causes a motor to follow a sophisticated velocity profile (**Fig 2**). Although you could use an analog tachometer, the digital one costs less, performs better, is less sensitive to temperature, and implements easier in a custom IC.

My design's tachometer controls the actuator for the heads of an optical-disk drive. But the principle also applies to other motor-control applications.

Upon receiving a start command, the actuators accelerate to a desired speed and follow the specified velocity profile until they reach their destination.

As the actuators move across the tracks, they generate two pulses for each track they cross. The circuit samples these pulses at different rates depending on how close the actuators are to their final destination. **Table 1** lists the specific sampling rates.

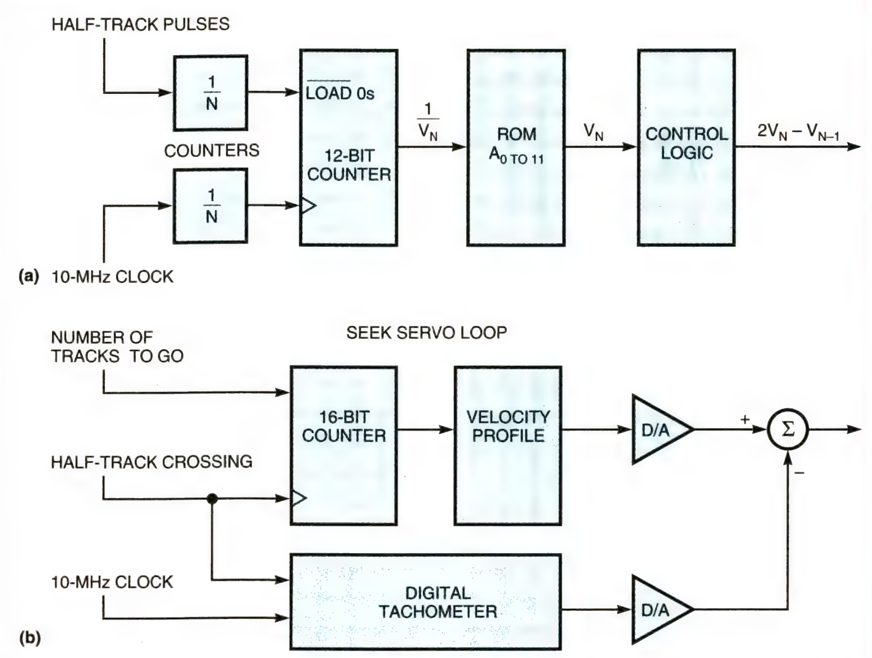
A 10-MHz clock provides the fundamental sample rate; but the actual sample rates vary. Therefore, the circuit must divide the time between samples by that same sample rate to obtain the correct time interval for each pulse. Otherwise, the output A/D converters would not produce a properly scaled error signal.

In **Fig 1**, two 4-bit counters divide the input-pulse signal and the 10-MHz clock by the appropriate divisor from **Table 1**. The overflow output of the input-pulse's 4-bit counter loads all zeros into the 12-bit counter. The 4-bit counter's overflow output clocks the 12-bit counter. Thus, the output of the 12-bit counter always represents the time required for a single input pulse, regardless of the sample rate.

A 4-kbyte PROM converts the output of the 12-bit counter to velocity. The circuit in **Fig 1b** compares the actual velocity with the desired velocity, producing an error signal for the actuator. (DI #1612) EDN

To Vote For This Design, Circle No. 374

FIGURE 1

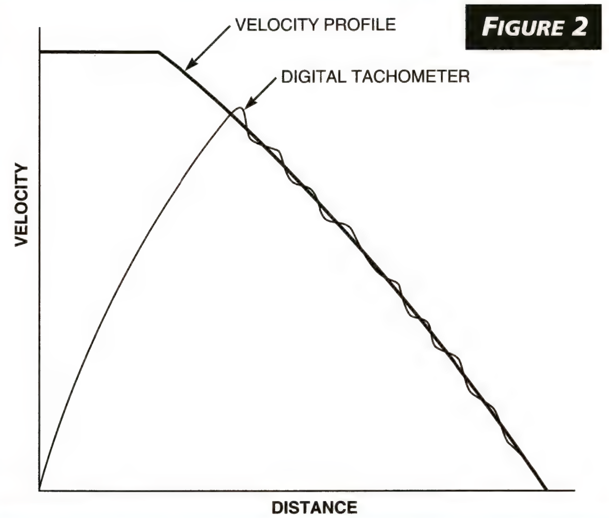


The digital tachometer in (a) cleverly adjusts its sampling rate to match varying rates of input pulses. The sampling rate varies as the actuator being controlled approaches its target (Table 1). The circuit in (b) compares the tachometer's output with the actuator's desired speed.

TABLE 1—DISTANCE TO DESTINATION VS SAMPLING RATE

Number of tracks to go	Pulse-sampling rate (2 pulses/track)
<425	16
425 to 153	8
152 to 68	4
67 to 7	2
6 to 0	1

FIGURE 2



After accelerating an actuator, the digital tachometer tracks the actuator's speed. This tracking produces an error signal, so the actuator follows a desired velocity profile as it homes in on its destination.

Software configures IBM PC interrupts

SAID JACKSON, CONSULTANT, HAMBURG, GERMANY

Anyone who has installed an expansion card in an IBM PC-AT expansion slot has dealt with interrupt conflicts. Often, despite the manufacturer's claims of "plug-and-play" compatibility, inserting a simple I/O card turns a fully functional computer into a brain-dead piece of equipment. Interrupt assignments and the possible resulting conflicts usually cause this pernicious problem.

Under software control, the circuit in **Fig 1** can dynamically assign an interrupt-channel to an I/O card based on available channels. (The new PCI bus from Intel uses the same methodology.)

The 8-bit ISA bus provides six external-interrupt lines for expansion cards. Because the assignment of these interrupts is not standardized, more than one card may come from its factory set to the same interrupt line.

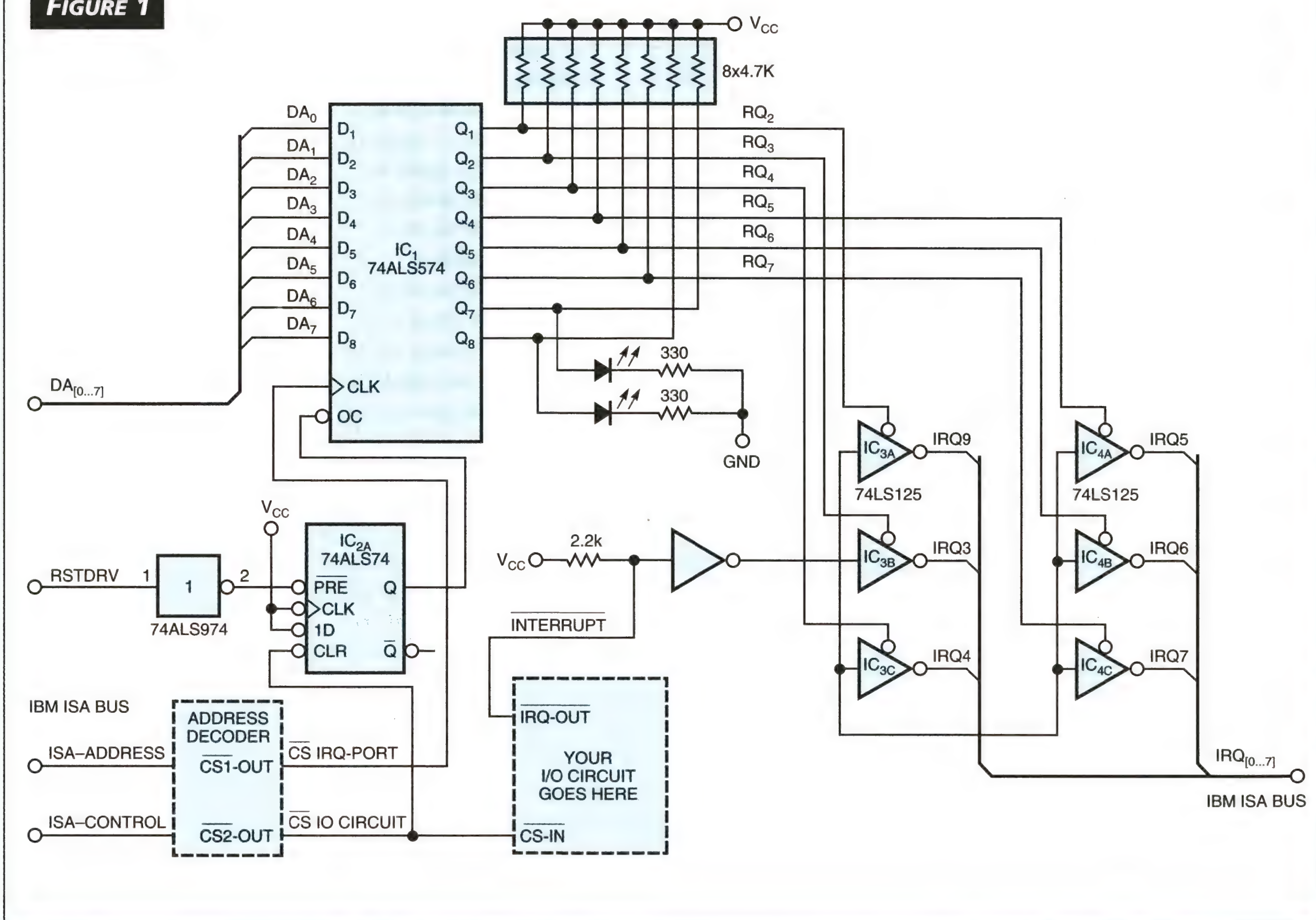
Now, multiple cards that use the same interrupt line are not necessarily bad. The ISA bus permits multiple cards assigned to the same interrupt. In fact, serial-I/O cards frequently use this scheme because PCs come hardwired with COM1 sharing an interrupt line with COM3 and COM2 with COM4.

But, in some cases, the interrupt-handler software cannot resolve such a conflict and the system crashes. Instead of forcing the user to troubleshoot the system by tediously changing jumper settings, the circuit allows the software to reconfigure the I/O board. Today's users demand such comfort and find any other setup highly anachronistic.

The heart of the circuit is an 8-bit register, IC_1, that stores the selected interrupt for the card. The software selects an interrupt line by writing a zero into the corresponding register bit. The software must first set all unselected interrupt bits to a logic 1. You can use the two leftover most-significant bits as general-purpose output bits. In our case, we used the bits to drive two status LEDs.

Your main concern is the circuit's cold-start behavior. The circuit must deactivate all interrupts upon power-up because the status of the register is undefined. The PC's reset-driver signal presets flip-flop IC_{2A} at power-up and disables IC_1's out-

FIGURE 1



A simple setup program can dynamically assign an interrupt-channel to an IBM PC's I/O card, based on currently available channels.

puts. The resistor pullups ensure that the tri-state interrupt line-drivers of IC_3 and IC_4 are inactive and can't assert any interrupts.

At this time, the interrupt driver can find a free interrupt line by checking the CPU's interrupt-vector table. After finding an unused interrupt, the software activates the add-in board's interrupt line by writing a logic 0 into its register. The system is active but not triggered.

The software initializes the board's I/O-port controller. The first chip-select of the I/O controller resets flip-flop IC_{2A}. In turn, this action activates the output of the interrupt register IC_1. Now the controller's interrupt requests can propagate through the 74LS125 drivers to the CPU. Pushing reset deselects all interrupts on the board, and the system is clear again.

This circuit works in both 8- and 16-bit IBM expansion slots. To use all available interrupts you need an IBM-AT, a second register, and some more 74LS125 drivers. (DI #1614)

To Vote For This Design, Circle No. 375

Oscillator keeps THD below 1 ppm

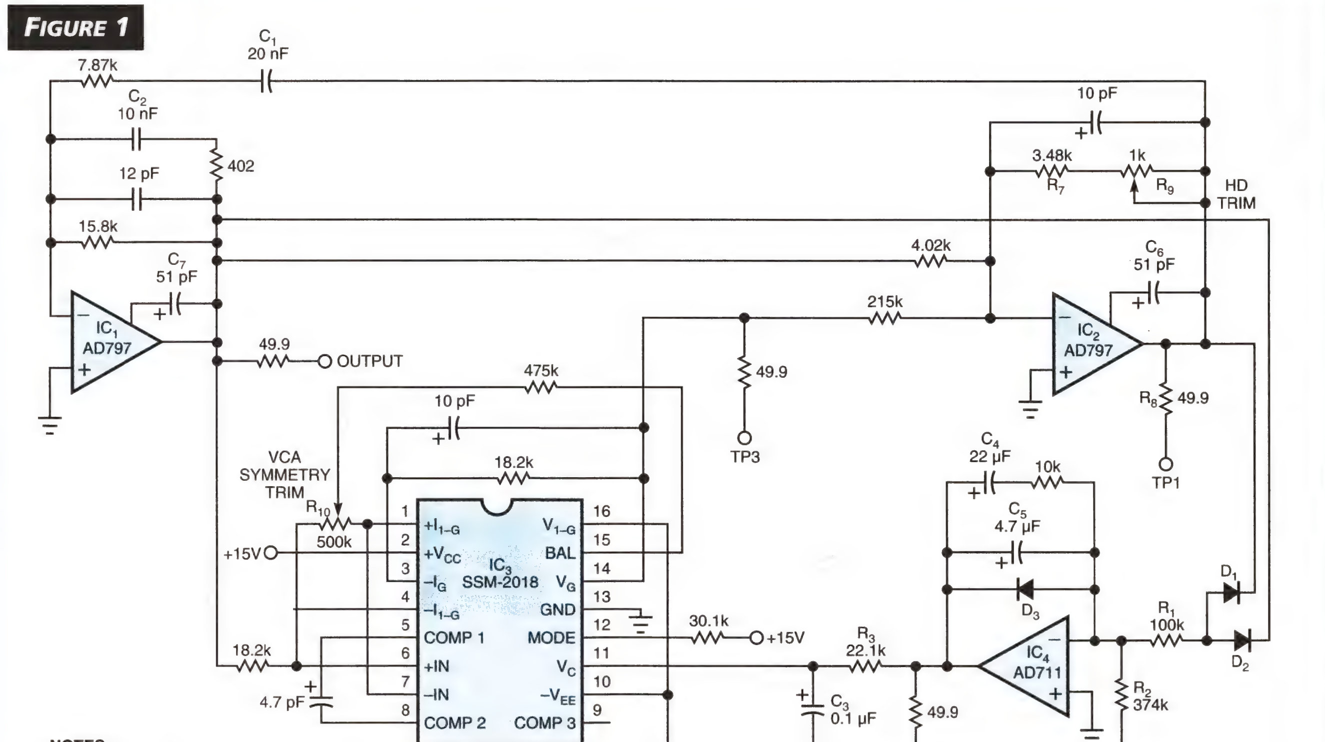
JEFF SMITH, ANALOG DEVICES, WILMINGTON, MA

The Wien-bridge sine-wave oscillator uses a light bulb to stabilize its amplitude. The circuit in **Fig 1** doesn't have a light bulb; it sports several enhancements that lower its distortion and generate a test signal pure enough for testing modern op amps and high-resolution A/D converters.

IC_1 and associated components form the Wien-bridge and function as a bandpass filter. IC_1's output goes to the voltage-controlled amplifier (VCA), IC_3. IC_3 acts as a "smart resistor" whose value the circuit continuously adjusts via IC_4. IC_2 adds the outputs of IC_1 and the VCA and feeds the result into the bridge. These two op-amp inverters eliminate any common-mode signal that might limit performance.

The circuit's AGC loop begins with diodes D_1 and D_2. These diodes half-wave rectify the outputs of IC_1 and IC_2.

FIGURE 1



NOTES:
1. ALL ICs BYPASSED WITH 0.1-µF CERAMIC CAPS ON EACH SUPPLY.
2. ALL ICs USE ±15V SUPPLIES.
3. ALL DIODES ARE 1N4148
4. C_1 AND C_2 ARE POLYSTYRENE, OUTSIDE FOIL AS SHOWN.
5. C_3 THROUGH C_8 ARE SILVER MICA.
6. R_9 IS A MULTITURN TRIMMING POTENIOMETER.

This Wien-bridge sine-wave oscillator sports several enhancements that lower its distortion and generate a test signal pure enough for testing modern op amps and high-resolution A/D converters.

SPDT switches with built-in driver

ABSORPTIVE or REFLECTIVE dc to 5GHz

Truly incredible...superfast 3nsec GaAs SPDT reflective or absorptive switches with built-in driver, available in pc plug-in or SMA connector models, from only $14.95. So why bother designing and building a driver interface to further complicate your subsystem and take added space when you can specify Mini-Circuits' latest innovative integrated components?

Check the outstanding performance of these units...high isolation, excellent return loss (even in the "off" state for absorptive models) and 3-sigma guaranteed unit-to-unit repeatability for insertion loss. These rugged devices operate over a -55° to +100°C span. Plug-in models are housed in a tiny plastic case and are available in tape-and-reel format (1500 units max, 24mm). All models are available for immediate delivery with a one-year guarantee.

SPECIFICATIONS (typ)	Absorptive SPDT YSWA-2-50DR ZYSWA-2-50DR			Reflective SPDT YSW-2-50DR ZYSW-2-50DR		
Frequency (MHz)	dc-500	500-2000	2000-5000	dc-500	500-2000	2000-5000
Ins. Loss (dB)	1.1	1.4	1.9	0.9	1.3	1.4
Isolation (dB)	42	31	20	50	40	28
1dB Comp. (dBm)	18	20	22.5	20	20	24
RF Input (max dBm)	—	20	—	22	22	26
VSWR "on"	1.25	1.35	1.5	1.4	1.4	1.4
Video Bkthru (mV,p/p)	30	30	30	30	30	30
Sw. Spd. (nsec)	3	3	3	3	3	3
Price, $ (1-9 qty)	YSWA-2-50DR (pin) 23.95 ZYSWA-2-50DR (SMA) 69.95			YSW-2-50DR (pin) $14.95 ZYSW-2-50DR (SMA) 59.95		

finding new ways...
setting higher standards

Mini-Circuits®

P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661

For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM • MINI-CIRCUITS' 740- pg. HANDBOOK.

F 185 Rev Orig

CUSTOM PRODUCT NEEDS...Let Our Experience Work For You.

These outputs are 180° out of phase; so IC_4 sees a full-wave rectified signal through R_1 that is proportional to the output signal's amplitude.

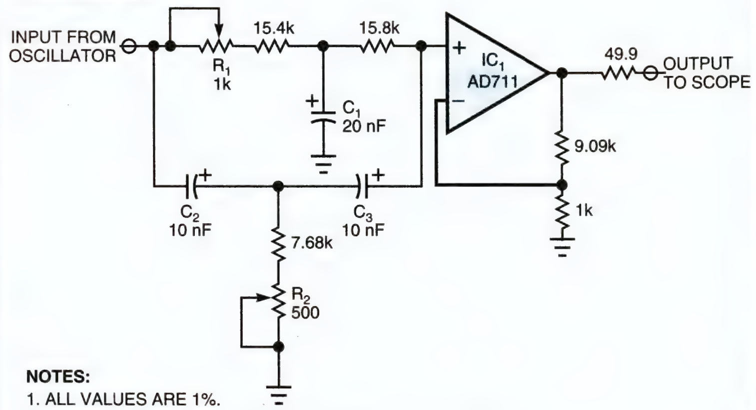
Integrator IC_4 compares the average value of the rectified current to a constant current through R_2. Any imbalance in these currents causes IC_4 to output a correction signal, changing the gain of VCA IC_3. The VCA's gain adjusts the oscillation's amplitude until IC_4's input currents are equal. R_3 and C_3 further filter the correction signal to remove harmonic components that would manifest themselves as distortion at the circuit's output. D_3 minimizes damage to C_4 and C_7 in the event of reverse polarization.

The ac performance of C_1 and C_2 is critical to this design. I recommend polystyrene or polypropylene film types; and make sure you connect the outside plate as **Fig 1** indicates. Mylar capacitors can degrade the circuit's performance by 6 dB. C_5 and C_6 are peculiar to IC_1 and IC_2. They eliminate distortion arising from V_{BE} nonlinearities in the op amps' output stages.

The large ratio of output signal to distortion and noise floor makes verifying the performance of this circuit with standard test equipment difficult. Therefore, I used the tunable, buffered-output, twin-T filter in **Fig 2** to reduce the fundamental (1 kHz) in the output by 70 dB. Spectral analysis of the filter's output permits calculation of THD.

When properly tuned, the filter reduces the second and third harmonics by about 10 and 5 dB, respectively. Harmonic-distortion calculations must take this reduction into account. Harmonic-distortion calculations must factor in the gain of IC_1 (**Fig 2**). Be sure to use the same high-performance capacitors used for C_1 and C_2 in **Fig 1** for C_1, C_2, and C_3 in **Fig 2**.

FIGURE 2



NOTES:
1. ALL VALUES ARE 1%.
2. BYPASS IC_1 WITH 0.1-μF CERAMIC CAPS ON EACH SUPPLY.
3. R_1 AND R_2 ARE MULTITURN TRIMMING POTENTIOMETERS.
4. C_1, C_2, AND C_3 ARE POLYSTYRENE.

Because the large ratio of output signal to distortion and noise floor makes verifying the performance of the circuit in Fig 1 difficult, you need this tunable, buffered-output, twin-T filter, which reduces the fundamental (1 kHz) in the output by 70 dB.

To tune the filter:

- Adjust R_9 so that R_7 shorts to R_8.
- Monitor TP3 on an oscilloscope and adjust R_{27} for a visually undistorted sine wave.
- Using the filter, adjust R_{10} for a minimum second-harmonic distortion at TP3.

Note: You may need to make small adjustments to R_9 for successful power up. (DI #1617) EDN

To Vote For This Design, Circle No. 376

Digital pot corrects for system drift

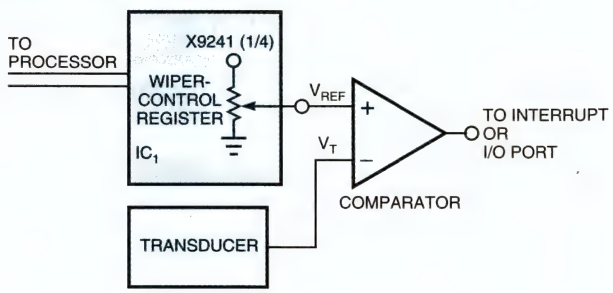
MARK RUTLEDGE, XICOR INC, MILPITAS, CA

The circuit in **Fig 1** looks simple but usually comes as a revelation to designers. Under control of the system's μP, the digital potentiometer, IC_1, becomes a variable set-point reference that can adapt to the long-term drift of the variable measured. The digital potentiometer replaces schemes involving A/D and D/A converters (see "Autocalibrator nulls dc offsets," *EDN*, June 9, 1994, pg 139, and "Infinite-hold circuit zeros out long-term drift," *EDN*, March 3, 1994, pg 90).

Depending on how you configure IC_1, its resolution will be 0.79, 0.53, or 0.40%. Cascading two devices yields 0.024% resolution. Internal EEPROM registers store the digital potentiometer's "wiper" position, allowing the system μP to determine the current set point, even after power outages. (DI #1615) EDN

To Vote For This Design, Circle No. 377

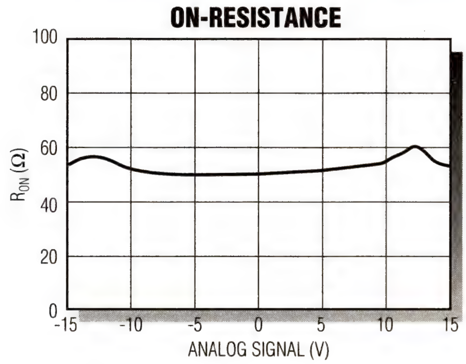
FIGURE 1



Under control of the system's μP, IC_1 becomes a variable set-point reference that can adapt to long-term drift of the variable.

100Ω CMOS MUXES DELIVER 5Ω MATCHING & 7Ω FLATNESS

Precision Muxes Are DG40X Plug-in Upgrades at No Extra Cost



The new MAX306-MAX309 reduce on-resistance variation over the specified analog signal range, thereby increasing system accuracy.

Maxim's new MAX306-MAX309 precision family of multiplexers upgrade the industry-standard DG406-DG409 and DG506A-DG509A. The MAX306-MAX309 are electrically equivalent and pin compatible. The improved electrical specifications increase system accuracy in precision data-acquisition systems by reducing signal errors caused by high on-resistance and leakage. On-resistance channel-to-channel matching, flatness, and charge injection have also been improved. Maxim's new muxes operate over a wide supply voltage range of +4.5V to +30V or ±4.5V to ±20V, with ESD protection >2000V.

- **Plug-in Upgrade for DG406-DG409, DG508A-DG509A**
- **Low Leakage <2.5nA at +85°C**
- **Dual Supplies ±4.5V to ±20V Single Supply +4.5V to +30V**
- **ESD Protection >2kV**
- **Low Power <1mW**

MAX306-MAX309 vs. DG406-DG409

	MAX306 MAX307	DG406 DG407	MAX308 MAX309	DG408 DG409
Number of Channels	16	16	8	8
On-Resistance Match (Ω)	5 (max)	5 (typ)	5	5 (typ)
On-Resistance Flatness (Ω)	7 (max)	Not Specified	7	Not Specified
Off-Leakage at 85°C (nA)	2.5 (max)	5	2.5	5
Charge Injection (pC)	10 (max)	15 (typ)	10 (max)	15 (typ)
ESD (V)	2000 (min)	Not Specified	2000 (min)	Not Specified
Price ($)*	3.87	3.87	2.50	2.50

FREE Mux & Switch Design Guide–*Sent Within 24 Hours!*
Includes: Data Sheets and Cards for Free Samples

CALL TOLL FREE 1-800-998-8800
For a Design Guide or Free Sample

MasterCard® and Visa® are accepted for Evaluation Kits or small quantity orders.

MAXIM

ISO 9001
Certificate Number: 30337

CIRCLE NO. 146

Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086, (408) 737-7600, FAX(408) 737-7194.

Distributed by Arrow, Bell, CAM RPC, Digi-Key, Elmo, Hamilton Hallmark, Nu Horizons, and Zeus. Authorized Maxim Representatives: **AL,** EnVision; **AZ,** Techni Source Inc.; **CA,** (Northern California) Maxim Integrated Products, (Southern California) Mesa, Infinity Sales, Inc.; **CO,** Component Sales; **CT,** Comp Rep Associates; **DE,** TAI Corporation; **FL,** Sales Engineering Concepts; **GA,** EnVision; **ID,** E.S. Chase; **IL,** Industrial Representatives, Inc; **IN,** Technology Marketing Group; **IA,** JR Sales Engineering, Inc.; **KS,** Delltron; **LA,** Maxim Integrated Products, Inc.; **MD,** Micro-Comp, Inc.; **MA,** Comp Rep Associates; **MI,** Micro Tech Sales; **MN,** Mel Foster Technical Sales, Inc.; **MO,** Delltron; **MT,** E.S. Chase; **NE,** Delltron; **NH,** Comp Rep Associates; **NJ,** Parallax, TAI Corporation; **NM,** Techni Source Inc.; **NY,** Parallax, Reagan/Compar; **NC,** EnVision; **OH,** Lyons Corporation; **OK,** Maxim Integrated Products, Inc.; **OR,** E.S. Chase; **PA** (Pittsburgh area) Lyons Corporation, (Philadelphia area) TAI Corporation; **SC,** EnVision; **TX,** Maxim Integrated Products, Inc.; **UT,** Luscombe Engineering Co.; **VA,** Micro-Comp, Inc.; **WA,** E.S. Chase; **WI,** Industrial Representatives, Inc.
Distributed in Canada by Arrow. Authorized Maxim Representative in Canada: Tech Trek.

*All prices are FOB USA.

Disassembler takes on 8-bit Intel µPs and µCs

K V RAMAKRISHNAN, DRDO, NPOL
COCHIN, KERALA, INDIA

The disassembler and documentation in the ZIPfile attached to EDN BBS /DI_SIG #1624 handles the object code for 8048, 8051, 8080, and 8085 family processors.

To Vote For This Design, Circle No. 378

µC routines clear up errors

MIKA MAASPURO, KIRSTINMAKI
ESPOO, FINLAND

The ZIPfile attached to EDN BBS /DI_SIG #1619 contains executable programs and source code for programs that allow you to program MC68HC11 microcontrollers via an RS-232C connection to your PC. The programs replace obsolete, error-laden programs published in an applications note.

To Vote For This Design, Circle No. 379

Spice filters allow experimenting without designing actual circuits

GEORGE ELLIS, KOLLMORGEN
RADFORD, VA

This ZIPfile attached to EDN BBS /DI_SIG #1620 contains some popular filters you can use with Spice models. Specified in terms of frequency and damping factor, the filter models allow you to experiment without having to design working filters.

To Vote For This Design, Circle No. 380

C program simulates industrial temperature system

JYOTI VANDANA, WORLD FRIENDS DESIGN GROUP
KALPAKKAM, TAMILNADU, INDIA

The program in the ZIPfile attached to EDN BBS /DI_SIG #1621, written in Borland C, simulates industrial-temperature-data display and control. It displays four independent channels simultaneously.

To Vote For This Design, Circle No. 381

Correction

"Passive components cancel phase errors," (*EDN*, June 9, 1994, pg 147) contains errors. The symbol for the load should be r, not R. The label for the inductor in the left-bottom branch of the bridge should be L, not L_1. The expression $F_O/2$ in the seventh line from the bottom of the first column of text should be $f_O/2$. Finally, omit the + signs from the capacitors; they are not electrolytics.

EDN DESIGN IDEAS

Design Idea Entry Blank

Entry blank must accompany all entries. $100 Cash Award for all published Design Ideas. An additional $100 Cash Award for the winning design of each issue, determined by vote of readers. Additional $1500 Cash Award for annual Grand Prize Design, selected among biweekly winners by vote of editors.

To: Design Ideas Editor, EDN Magazine
275 Washington St, Newton, MA 02158

I hereby submit my Design Ideas entry.

Name ______________________

Title ______________________

Phone ______________________

Company ______________________

____

Address ______________________

____

____

____

Country ______________ ZIP ________

Design Idea Title ______________________

____

Social Security Number ______________________
(US authors only)

Entry blank must accompany all entries.
Design entered must be submitted exclusively to EDN, must not be patented, and must have no patent pending. Design must be original with author(s), must not have been previously published (limited-distribution house organs excepted), and must have been constructed and tested. Fully annotate all circuit diagrams. Please submit software listings and all other computer-readable documentation on a IBM PC disk in plain ASCII.

Exclusive publishing rights remain with Cahners Publishing Co unless entry is returned to author, or editor gives written permission for publication elsewhere.

In submitting my entry, I agree to abide by the rules of the Design Ideas Program.

Signed ______________________

Date ______________________

Your vote determines this issue's winner. Vote now, by circling the appropriate number on the reader inquiry card.

LINEAR TECHNOLOGY

DESIGN NOTES

High Efficiency Power Sources for Pentium™ Processors

Design Note 90

Craig Varga

In many applications, particularly portable computers, the efficiency of power conversion is critical both from the standpoint of battery life and thermal management. Desktop machines may also benefit from higher efficiency, particularly a "green PC." While linear regulators can offer low cost and high performance solutions, they can only offer 67% efficiency in 5V to 3.3V applications. Switching regulators are more efficient and minimize or even eliminate the need for heat sinks at a higher cost for the components. Efficiencies around 90% are routinely obtained with Linear Technology's best regulator designs (see Figure 2). The LTC1148 based circuit (Figure 1) meets the requirements of the P54-VR specification for output voltage transient response with the indicated decoupling network.

Selection of Input Source

Several options exist as to where to derive raw power for the regulator input. In most desktop systems a large amount of 5V power is available. Also, there is usually a reasonable source of 12V at hand. The 5V supply will most likely have the highest power output capability since it is called upon to power the bulk of the system logic. This logic can be sensitive to voltage changes outside of ±5%.

When the processor draws large transient currents, the 5V supply will be perturbed. In all "buck" type switching regulators there is an inductor in the path between the raw input supply and the load. This has the effect of limiting the rise time of the input currents and minimizing the disturbance to the 5V supply. However, the typical cheap off-line "brick" supply has terrible transient response, and the 5V

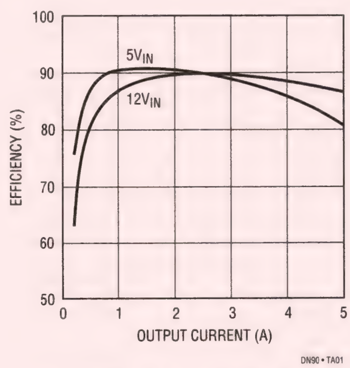


Figure 2. Efficiency vs Load

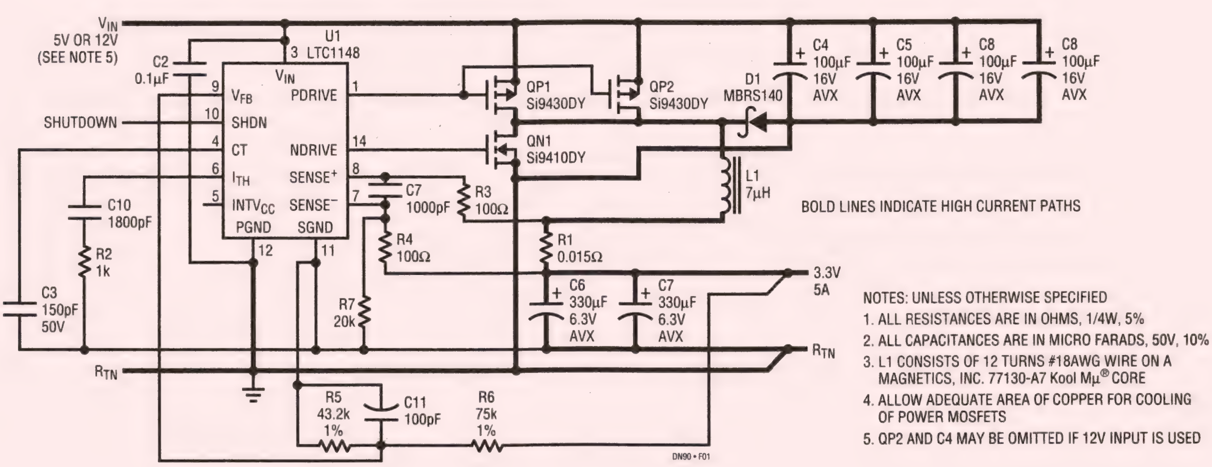


Figure 1.

supply may still be disturbed enough to cause logic problems. This is especially true as the load currents rise to the levels expected in multiprocessor systems.

If this is the case, using the 12V supply may prove advantageous. Since the 12V supply is not directly regulated, nothing that is terribly sensitive to voltage level is normally powered off the 12V bus. Moreover, with switching regulators, as a first order approximation, as the supply voltage rises the input current drops. As such, even though the input power is nominally the same whether running from a 5V or 12V supply, the current requirement is much lower if 12V is utilized for the input source.

The downside of 12V operation is lower light load efficiency than 5V operation. The efficiency with a 5V input powering a 3.3V switcher is likely to be several percentage points better than at 12V due to a reduction in switching losses. Every situation is somewhat different and a thorough analysis of the trade-offs must be undertaken to optimize the design. The schematic shown in Figure 1 offers the option to run from several supply choices. Each circuit was optimized for the specified input voltage, but will function well over a fairly wide range of supply voltages.

Transient Response Considerations

As with a linear regulator, the first several microseconds of a transient are out of the hands of the regulator and dropped squarely in the lap of the decoupling capacitor network. In the case of the switcher, the ultimate response of the regulator will be quite slow compared to a linear regulator. In the circuits shown, the approximate time required to ramp the regulator current to equal the high load condition is 11μs, about 2.4 time that of an LT1585 high speed linear regulator in the same application. This means in layman's terms, that the LT1585 linear regulator requires less bulk capacitance than the LTC1148 switcher solution.

Circuit Operation

Figure 1 is a schematic of the two regulators. For the 12V input, omit QP2 and C4. The design is a standard synchronous buck regulator that is discussed in detail in several Linear Technology Application Notes as well as the LTC1148 data sheet. Since the required output voltage is not the standard 3.3V, which is available factory set, an adjustable regulator is used. R5 and R6 set the output voltage to the desired level, in this case 3.38V. R7 is used to inhibit Burst Mode™ operation at light loads. If the system were permitted to operate in Burst Mode, the output voltage would rise by about 50mV at low load currents. If added low load efficiency is desired and the slightly higher low load output voltage can be tolerated, this resistor can be omitted.

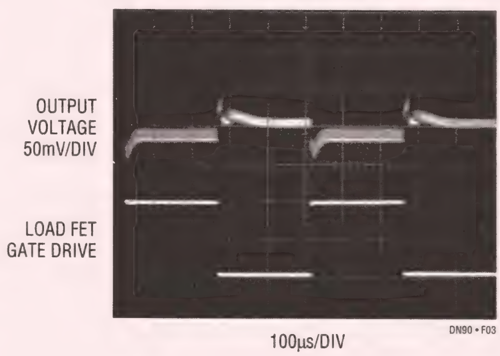
Burst Mode is a trademark of Linear Technology

To meet the transient requirements of the P54-VR, a fairly large amount of capacitance is needed beyond what is required to make the regulator function correctly. A viable decoupling scheme is to use 10 each, 1μF surface mount ceramics and 7 each, 220μF, 10V surface mount tantalums at the processor socket. In addition to the socket decoupling, two pieces of a 330μF, 6.3V surface mount tantalums are required at the power supply.

The input capacitors were selected for their ability to handle the input ripple current. At a 5A load current this is a little over 4A with a 5V input and 2.6A for a 12V input. The capacitors are rated at slightly over 1A each at 85°C. If the input can be switched on very rapidly, the input capacitor voltage rating should be at least two times the supply voltage to prevent dV/dt failures.

By running the operating frequency at 150kHz, the small inductor used is sufficient. Also, since the design is synchronous, the ripple current may be permitted to get quite high without causing any problems for the regulator control loop. This would not be true in a non-synchronous design. A major advantage of high ripple current is the regulator's ability to ramp output current rapidly. The rate of rise of output current is directly proportional to input/output differential and inversely proportional to the inductor value. Using a small inductor aids in achieving fast response to transients.

5V Input, 0.2A to 4A Load Step



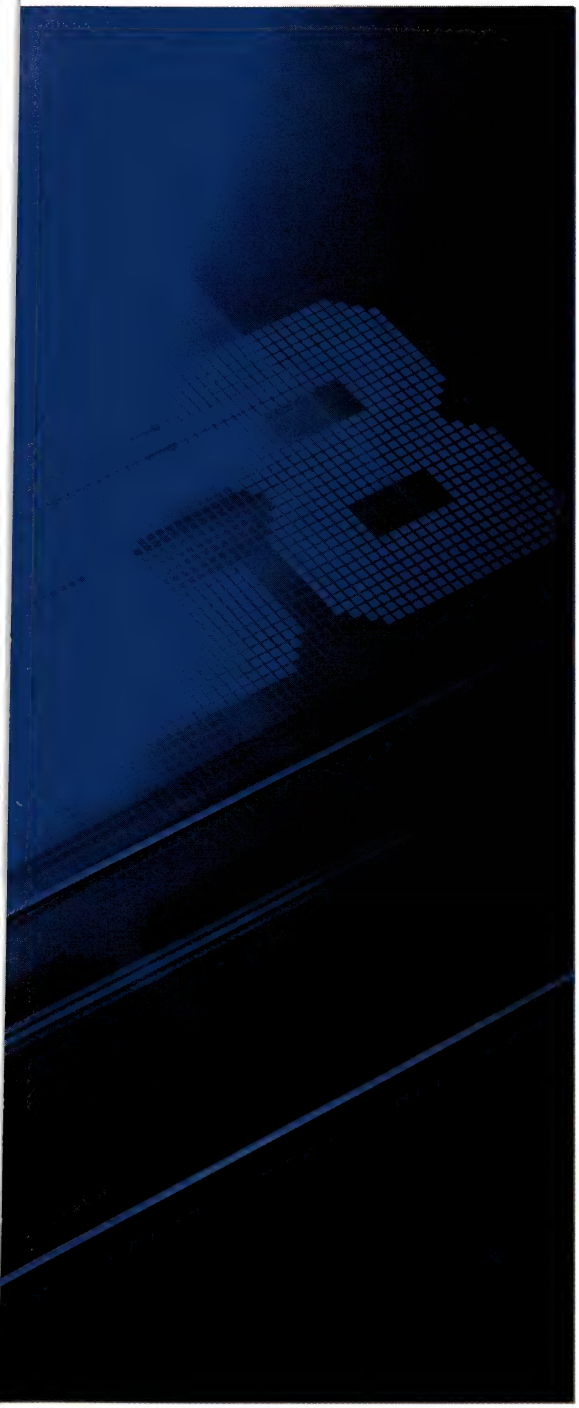
Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7487
(408) 432-1900 • FAX: (408) 434-0507 • TELEX: 499-3977

LT/GP 1194 190K • PRINTED IN THE USA


Multilayer Ceramic Chip Capacitors, CC0402 Series
A compact CC0402 size, featuring large capacitance extending to 33,000pF.
CAPACITANCE RANGE: 0.5 to 33,000pF.
DIMENSIONS: 1.0×0.5mm (.039×.020″).
Thin-Film Printed Chip Inductors, NLU Series
High-performance chip inductors for use in high-frequency circuits up to 3GHz.
FREQUENCY: 300MHz to 3GHz.
Q: 20 min. L: 2.075 to 8.913nH ±0.2nH/L: 10.43 to 53.39nH±2%.
DIMENSIONS: 2.02×1.25×0.58mm (.080×.049×.023″).
EMI Suppressor Arrays, ACA Series
Chip array incorporating four ferrite chip beads with a pitch of 0.8mm(.031″), and thus enabling joint digital EMI suppression in four signal lines.
IMPEDANCE: 60 to 600Ω (100MHz).
DIMENSIONS: 3.2×1.6×0.9mm to 5.0×2.0×0.9mm (.126×.063×.035″ to .197×.079×.035″).
Multilayer Ceramic VCO, QVC Series
Realizes more compact size, lower power consumption and higher C/N.
FREQUENCY: 800MHz to 1.9GHz.
DIMENSIONS: 10.0×7.0×2.5 to 3.5mm (.394×.276×.098 to .138″).
TDK CHIP COMPONENT STARS ARE WAITING TO BE DISCOVERED.
Duplexers for Cordless Phones, HHM-0120 Series
Having an internal harmonic suppressor filter, the HHM-0120 can be used for both hand set and base.
DIMENSIONS: 7.5×5.0×1.0mm (.295×.197×.039″).
Miniature Isolators for Cordless/Cellular Phones (Digital & Analog), CU407 Series
Lowest insertion loss yet, plus high stability through temperature changes.
FREQUENCY: 800MHz to 2GHz.
INSERTION LOSS: 0.9dB max.
DIMENSIONS: 7.3×7.3×4.0mm (.287×.287×.157″).
TDK supplies a wide range of high-performance SMD components, including those for general use, cordless/cellular phone and EMI-Suppression, plus those designed to respond to numerous advanced user applications. Our products include multilayer ceramic chip capacitors, multilayer chip inductors, multilayer chip EMI filters, voltage controlled oscillators (VCO) and many other, all developed from our own materials. Above, we introduce some of our outstanding new products.
Call or write TDK today for a free SMT catalog.
TDK®
TDK CORPORATION OF AMERICA 1600 Feehanville Drive, Mount Prospect, IL 60056, USA Phone: 708-803-6100 INDIANAPOLIS Phone: 317-872-0370 NEW YORK Phone: 908-494-0100 SAN JOSE Phone: 408-437-9585 LOS ANGELES Phone: 310-539-6631 DETROIT Phone: 313-462-1210 BOSTON Phone: 508-624-4262 HUNTSVILLE Phone: 205-464-0222 GREENSBORO Phone: 910-292-0012 DALLAS Phone: 214-506-9800
GERMANY•FRANCE•ITALY•U.K.•KOREA•TAIWAN•HONG KONG•SINGAPORE•THAILAND•CHINA•BRAZIL
TDK CORPORATION Tokyo, Japan
CIRCLE NO. 207

Systems on silicon ente

he 3V era.



New 0.5-micron, Cell-Based ASICs run 50% faster, consume 70% less power.

Systems on silicon have reached a higher level of performance and a lower level of power consumption with the introduction of NEC's 0.5-micron, Cell-Based ASICs. Optimized for true 3V operation, our CB-C8 family offers exciting new possibilities for designers of telecom, personal computer and consumer systems.

CB-C8 ASICs give you a loaded speed of 220 picoseconds,* power dissipation of only 0.8μW/MHz/cell and high integration of up to 600,000 gates. Compared to our previous generation of 0.8-micron ASICs, the new family offers a 50% boost in speed and a 70% drop in power consumption. *F/0=2, L=2mm, power gate

Since speed to market counts almost as much as internal system speed, we offer a comprehensive cell library to facilitate your development of 3V systems on silicon. Macros include:

- ☐V30MX CPU (33MHz, 8086-compatible)
- ☐PLL, GTL, PCI* and RAMBUS®*
- ☐A/D and D/A converters*

*under development

Our OpenCAD® Design System also helps to shorten the development cycle. A unified front-to-back-end design package, OpenCAD allows you to mix and match our tools with those of the industry's most popular vendors.

Fast enough to match speeds with the industry's foremost microprocessors, yet featuring exceptionally low power dissipation, our CB-C8 ASICs offer a no-compromise solution to your design needs. For more information on how the CB-C8 family can improve performance for your cellular phone, personal digital assistant, multimedia platform, graphics system, PC or workstation, call NEC today.

CIRCLE NO. 157

NEC

For fast answers, call us at: USA Tel:1-800-366-9782. Fax:1-800-729-9288.

Combine software tools to devise your own FPGA-verification environment

LEO BREDEHOFT, NETRIX TELCOM SYSTEMS, BOULDER, CO

Armed with working knowledge of a modeling language such as VHDL and a simulator, you can verify an FPGA's design and reduce prototype-debugging time. This article discusses verifying FPGA designs and provides concrete examples demonstrating this practical, low-cost approach.

Many characteristics of FPGAs (field-programmable gate arrays) make preprototype design verification necessary. FPGA designs frequently contain buried states that you cannot probe in a prototype. Modification to FPGA's designs can prove costly. Place-and-route software that runs for some FPGAs can require as long as a day to complete. So, even for reprogrammable FPGAs, preprototype design verification can save development time.

To raise your level of confidence in the buried logic in an FPGA's design, you can simulate the design to verify it before ever fabricating pc boards. Here's how: You must first build a programmatic environment around your design. You then exercise your design by forcing all of its state sequences and generating as many asynchronous stimuli for the design as possible. Design verification can increase your chances of having a functional device when you initially install it in a prototype.

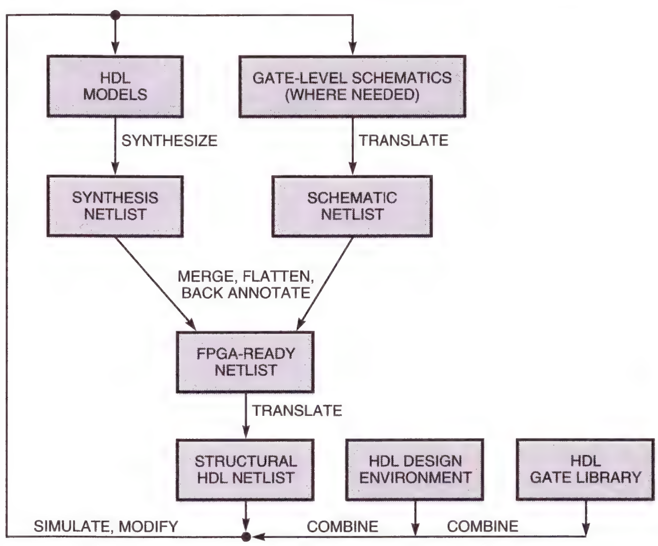
Development environment

Fig 1 shows the FPGA development environment best suited to the kind of design verification described in this article. You code most of your design environment in an HDL (hardware-description language) to keep your development time short and produce maintainable source code. Because of space and performance requirements, you draw gate-level schematics wherever necessary.

Both design methods produce netlists. You merge the resulting netlists and "back-annotate" them using tools from the FPGA vendor. A simple reformatting utility then converts the back-annotated, merged netlist into a flat, structural HDL model that is ready for simulation. You can use reformatting utilities to perform this last conversion. The reformatting is not likely to insert undetectable errors.

The last step combines your design's model with a set of HDL models of your design's operational environment and gates from a library for the gates invoked in your FPGA's netlist. The resulting total model allows you to simulate and iterate your design. This collection of models, in conjunction with the accompanying scripts and conversion programs, constitute the design-verification environment.

FIGURE 1



This FPGA development environment suits design verification. Most of the design environment is in an HDL; where necessary, you draw gate-level schematics.

BBS

The software listings in this article are available on *EDN's* computer bulletin-board system (BBS). Phone (617) 558-4241withmodem settings 300/1200/2400 8,N,1. After signing on,enter "ss/freeware". Then enter "rkms839".

You *could* use a gate-level simulator for design verification, but you generally do not have the option of coding an HDL design environment with a gate-level simulator. An HDL-based environment has a significant advantage over a gate-level environment. Gate-level simulators efficiently emulate networks of gates, but they can't run actual program code to generate complex signal-transition sequences. Typically, you must enter long sequences of test vectors to exercise a design. If a gate-level simulator offers any programmatic facility to aid in generating vectors, the programmic facility is usually very limited. The HDL-based environment permits you to avoid the tedious job of generating vectors.

Design preparation

To make your design simulatable under an HDL simulator, you must first convert your design from the FPGA vendor's netlist format into the HDL. HDLs can simulate designs only in a certain format. After back-annotation, your FPGA design may be in the form of a netlist file, such as EDIF (Electronic Design Interchange Format) or a vendor-specific format. Luckily, these formats translate simply and directly into *structural* HDL.

Structural HDL specifies logic at the lowest level and, in many cases, invokes the raw FPGA macros. Structural HDL is the equivalent of a schematic in text form, whereas behavioral HDL specifies a design's operation by a computer-program segment. These behavioral program segments are usually more versatile, understandable, and maintainable than structural code.

Now that you have back-annotated your FPGA's netlist with timing information, you are ready to convert the netlist into the HDL's format. You perform this conversion using standard text-formatting utilities such as the Unix stream editors *awk* and *sed* (**Ref 1**) and GNU's more capable *perl* (**Ref 2**) along with an ASCII file-sorting utility. Learning how to program these utilites should take you no more than a day or two. If you work on a PC, you might want to exploit a word processor that offers a powerful macro language for this ASCII file conversion. But, I have never seen a text editor that exhibits the flexibility and utility of *perl*. (PC versions of these programs are available.) This conversion job is straightforward because of the strict one-to-one mapping from gates and associated delays in the FPGA vendor's netlist format to gates and delays in the HDL.

Keeping this part of the method automated is important. If you do not let your computer do the work of reformatting netlists and other EDA tools' outputs, each recompilation of your design will require you to manually convert the FPGA's netlist into an HDL bus using a text editor.

You must also obtain a library for the gates your design uses. Some FPGA vendors may sell libraries for timing simulation of their parts in HDL source form. If not, writing models for a simulation library is not difficult. Combinatorial gates typically use a simple, per-input propagation-delay model. In such models, each input to the gate has a delay associated with it. The specified delay is the sum of the wire delay from the output driving the input and the delay from the input to the modeled gate output. Specifying such gates parametrically is trivial in an HDL gate model. Latches and flip-flops are more complex because of their requirement for checking input timing such as setup and hold times. But, you can also write latch and flip-flop modes with relative ease.

Fig 2a shows one FPGA design well-suited to verification

LISTING 1—COMBINATORIAL MODEL AND MAPPING EXAMPLE

```
library ieee;
use ieee.std_logic_1164.all;

entity ao1 is
     port (signal a, b, c : in std_logic; signal y : out std_logic);
end ao1;

architecture structural of ao1 is begin
     y <= (to_x01(a) and to_x01(b)) or to_x01(c);
end structural;
```
(a)

```
MM4983 : ao1
    port map(
         A => DS_8273'DELAYED(12.4 ns),
         B => OCTL_0_CCLRPEND'DELAYED(9.1 ns),
         C => OMS_BPWRITE'DELAYED(11.4 ns),
         Y => OCTL_0_116
    );
```
(b)

DESIGN VERIFICATION IS NOT THE SAME AS TESTING

Do not confuse this article's design verification with the action of a thorough set of test vectors. Test vectors toggle and observe all nodes in a chip to ensure that the chip itself is intact, but test vectors do not pay particular attention to the actual function of your design. Design verification, on the other hand, simply attempts to ensure that your design is correct for the application. Design verification ignores such testing obstacles as duplicated structures that operate correctly even if only one instance of the structure is correct.

For example, a set of thorough test vectors would pass ones and zeros through each section of a 16-bit, 2-to-1 multiplexer. But, a design verification examines only a convenient subset of the multiplexer's functions, relying upon synthesis tools or macro definitions to ensure that untested portions of the multiplexer are correct. If a certain hexadecimal number goes into an input of the multiplexer and appears at the output, one side of the multiplexer's design is verified.

Test vectors *are* necessary for masked gate arrays to eliminate the cost of packaging chips that may be identified as nonfunctional at the wafer-probe stage. But, FPGAs do not necessarily need such a set of test vectors. RAM-based FPGAs are completely tested at the factory and don't need additional testing. Makers test hard-wired FPGAs at their factories, and this testing provides a higher confidence level than with masked gate arrays.

Even in the case of hard-wired FPGAs, test vectors are not a necessity for every design, as long as in-system diagnostics and operational testing exercise the parts thoroughly. And, given the cost per gate of FPGA logic, inclusion of scan-path logic for testability is an option that many designers are not willing to consider.

using this article's techniques. The design is a display-list-based video-monitor controller. The FPGA formats display-list data from list memory and transfers the information to the serializer. The serializer then sends the data to the video monitor. The FPGA also arbitrates the microprocessor's access to the list memory.

To adapt this design to a design-verification environment, you must convert the netlist for the FPGA into the HDL and write models to emulate each of the system elements surrounding the FPGA.

For the most part, these surrounding models are probably behavioral models. Behavioral models respond to input-signal transitions by executing a computer-program fragment each time an input of interest changes. These program fragments can do just about anything a normal application program can: read and write files, maintain internal data structures, and print messages.

If you carefully apply this sequential, programlike behavior, you can expeditiously emulate behavior that would be too complex to implement with a structural model. This programlike behavior can also provide high-level indications of a design's functions that a human can easily understand and examine. Probably, the most valuable aspect of using behavioral models for design verification is that you do not have to verify a circuit's functions via tedious and error-prone examination of ones and zeros. Instead, the model formats the information into its most recognizable form for quick, high-confidence examination.

Fig 2b shows the modeled equivalent of the system. The microprocessor model performs reads and writes specified in an access file. The list memory reads in its contents upon initialization but otherwise behaves like a static RAM.

The video-monitor model performs serial-to-parallel conversions of data from the serializer and outputs the information to a sequence of raster files. You can physically output the raster files later to a graphics screen and verify the raster files visually. Viewing the raster files is a powerful verification tool that provides a level of confidence that you could never achieve by simply examining signal traces in the simulator. For instance, if an arbiter bug in the FPGA were

LISTING 2—FLIP-FLOP MODEL AND MAPPING EXAMPLE

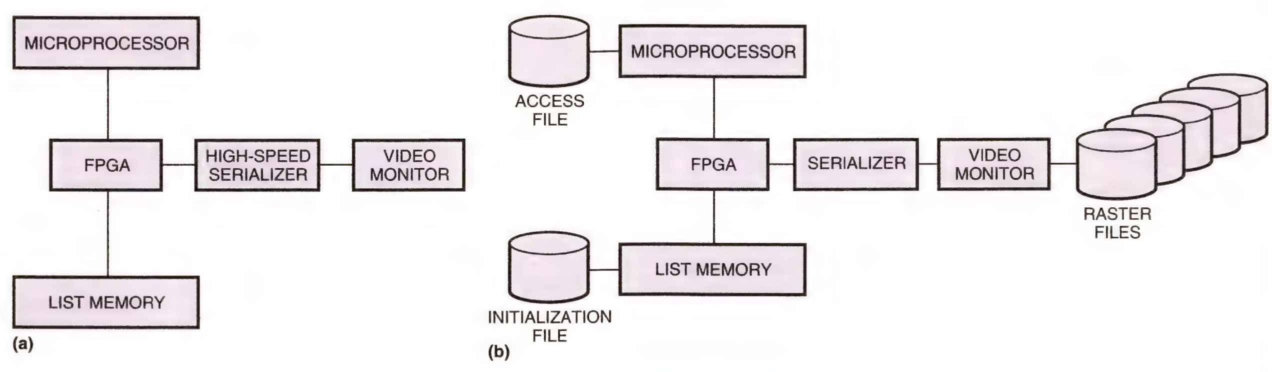
```
library ieee;
use ieee.std_logic_1164.all;

entity dfc1 is
     generic (
          constant tHASYNC, tHD, tPWASYNC, tPWCLK, tRECASYNC, tSUD
               : in time := 0 ns
     );
     port (
          signal clk, clr, d : in std_logic;
          signal q : inout std_logic := 'W'
     );
end dfc1;

architecture sequential of dfc1 is
begin
     process (d,clk,clr,q)
          variable firsttime : boolean := true;
     begin
          if (firsttime and q'EVENT and (q = '0' or q = '1')) then
               q <= q;                              -- latch forced state
               firsttime := false;
          end if;
          if (clr = '0') then
               if (clk'EVENT and clk = '1') then
                    assert now-d'LAST_EVENT >= tSUD
                         report ("DFF d setup violation")
                         severity ERROR;
                    if (to_x01(d) = 'X') then -- prevent unknown flood
                         q <= '0';
                    else
                         q <= to_x01(d);
                    end if;
                    firsttime := false;
               end if;
               assert not (d'EVENT and clk'LAST_EVENT < tHD)
                    report ("DFF d hold violation")
                    severity ERROR;
          end if;
          if (clr = '1') then
               q <= '0';
          end if;
     end process;
end sequential;
```

(a)

```
MM4984 : df1
     generic map(
          tHD => 0 ns,
          tPWCLK => 7.9 ns,
          tSUD => 0.7 ns
     )
     port map(
          CLK => CLOCKI'DELAYED(14.5 ns),
          D => OCTL_0_SPCHTXC_D'DELAYED(7.7 ns),
          Q => SPCHTXCO
     );
```

(b)

FIGURE 2



The design in (a) is a display-list-based video-monitor controller. Its FPGA formats display-list data from list memory and transfers it to the serializer, which sends the data to the video monitor. The FPGA also arbitrates the microprocessor's access to the list memory; (b) is the modeled equivalent of the system in (a). The microprocessor model performs reads and writes specified in an access file.

FPGA DESIGN-VERIFICATION ENVIRONMENT

causing the microprocessor's accesses to corrupt the output to the monitor, the problem would be immediately apparent in the raster output.

High-level verification of this sort is not limited to this design. The general principle applies to many types of designs. A word of caution: This technique is not a substitute for a conscientious examination of the entire simulation output. Each design has its own set of subtle failure modes and bugs that requires your close attention. High-level verification remains a crucial tool, but not the total solution.

Model implementation

The remaining portion of this article details actual HDL examples of typical models. The code is in VHDL (**Refs 3** and **4**), although the general principles should apply other HDLs as well. The VHDL *value system* used is the IEEE standard std_logic_1164 package. The term "value system" refers to a set of possible logic values that a signal may carry: "X" for unknown, "1," "0," and many others. The VHDL references clarify the exact use of these values.

Perhaps the simplest HDL models to write are models for combinatorial gates in your FPGA's library. In **Listing 1a**, the model for an AND/OR gate uses a simple, concurrent signal assignment to model the gate. The *architecture* section specifies the logical relationship between the inputs *a,b,c,* and the output *y*. The function *to_x01()* converts the nine-valued *std_logic* signals into the simple *"x," "0,"* and *"1"* values suitable for use by the signal assignment.

Listing 1b shows an actual invocation of **Listing 1a**'s gate in the converted FPGA netlist. The numbers in the DELAYED clauses come directly from the back-annotated wire delays. The *port map* statement associates each of the pins of the model (*a,b,c,* and *y*) with an actual signal. For each of the inputs, the *port map* statement also specifies the delay from the driving pin on the signal to the associated input. The term for these delays is "wire delays." The back-annotation program inserts these wire delays into FPGA netlists. In front of the invocation, *MM4983* is a slightly modified form of the label for the gate as it appeared in the original FPGA netlist.

Flip-flop model

The FPGA-simulation library (and possibly the models in the environment) may need another model, such as a flip-flop or latch. **Listing 2a** shows a basic flip-flop model from

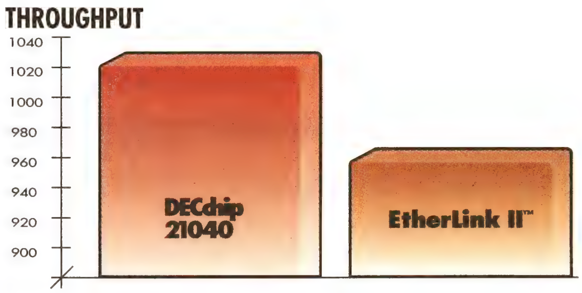
LISTING 3—MICROPROCESSOR MODEL

```
library ieee;
use ieee.std_logic_1164.all;
use std.textio.all;
use work.io_utils.all;

entity mp is
     port (
          clock : in std_logic;                          -- clock for
delays
          md : inout std_logic_vector(7 downto 0);       -- uP data
          ma : inout std_logic_vector(14 downto 0);      -- uP address
          csN : inout std_logic := '1';                  -- slave chip
select
          wrN : inout std_logic := '1';                  -- uP write
strobe
          rdN : inout std_logic := '1';                  -- uP output
strobe
          ack : in std_logic                             -- acknowledge
pulse
     );
end;

architecture sequential of mp is

  -- Timings

     constant tARSU : time :=  40 ns;         -- address
     constant tSTB  : time :=  45 ns;         -- strobe deassertion
delay
     constant tRDSU : time :=  20 ns;         -- read data setup to
ack
     constant tBTO  : time :=  10 us;         -- bus timeout
     constant tTOCL : time :=  600 ns;        -- bus timeout clear
time

     procedure ackwait is begin
          wait on ack for tBTO;
          if not rising_edge(ack) then
               assert false
                    report "uP timeout waiting for ack"
                    severity error;
          end if;
     end ackwait;

begin
     process                                          -- bus cycler
           file f : text is in "mp.dat";
           variable l : line;                         -- input record
           variable l1 : line;                        -- output print
record
           variable ck : integer := 0;                -- clock specifier
           variable addr, data : integer;             -- numeric command
fields
           variable rw : character;                   -- read/write select
           variable currentclock : integer := 0;   -- clock cycle
counter
           variable tmp : std_logic_vector(31 downto 0);   -- VHDL

     begin
          readline(f,l);
          while not(endfile(f)) loop

               while l'LENGTH /= 0 and l(1) = '#' loop -- skip
comments
                    readline(f,l);
               end loop;

               if l'LENGTH /= 0 then                     -- skip blank
lines
                    -- Get fields

                    -- Format: <clock number> r|w <address> [<data>]

                    read(l,ck);
                    read(l,rw);
                    read(l,addr,16);
                    if rw = 'w' then
                          read(l,data,16);
                    end if;
                    -- Wait for the specified clock cycle

                    while (currentclock < ck) loop
                        wait on clock;
                        if (clock = '1') then
                             currentclock := currentclock+1;
                        end if;
                    end loop;

                    -- Execute the bus cycle

                    tmp := to_x01(addr);          -- drive address
                    ma <= tmp(14 downto 0);
                    csN <= '0';                   -- chip select
                    if rw = 'r' then              -- read cycle
                         md <= "ZZZZZZZZ";
                         wait for tARSU;
                         rdN <= '0';
                         ackwait;
                         if not rising_edge(ack) then -- timeout
recovery
                              rdN <= '1';
                              csN <= '1';
                              wait for tTOCL;
                          end if;
                          assert md'LAST_EVENT >= tRDSU
                               report "MP data to ack setup
violation"
                               severity error;
                          data := to_int(md);    -- print read data
                          write(l1,string'("Memory read "));
                          write(l1,addr,right,4,hex,false);
                          write(l1,string'(" returns "));
                          write(l1,data,right,2,hex,false);
                          writeline(output,l1);
                    elsif rw = 'w' then           -- write cycle
                          tmp := to_x01(data);
                          md <= tmp(7 downto 0);
                          wait for tARSU;
                          wrN <= '0';
                          ackwait;
                          if not rising_edge(ack) then -- timeout
recovery
                               wrN <= '1';
                               csN <= '1';
                               wait for tTOCL;
                          end if;
                    end if;
                    wait for tSTB;
                    wrN <= '1';
                    rdN <= '1';
                    csN <= '1';
                    wait on ack;                  -- deassertion
                 end if;
               readline(f,l);                     -- next record
          end loop;
          wait until false;                       -- hang when done
     end process;
end sequential;
```

SEMICONDUCTORS FROM DIGITAL

OUR NEW PCI ETHERNET CHIP PUMPS BITS LIKE YOUR LIFE DEPENDED ON IT.

When throughput is critical, hook up to our new 21040 PCI Ethernet controller chip and let the data flow. With our full 32-bit implementation, you'll get pure, unadulterated power. No 16-bit baggage. No bottlenecks. No compromises. And you'll get CPU utilization as low as 12%—low enough to support multiple Ethernet connections on a single NIC. This chip is fast. It's efficient. It's downright heroic. And it's just the beginning of a steady stream of



PCI chips coming from Digital Semiconductor, the leader in PCI technology. Call us for more information. And hurry. The design you save may be your own.

CALL 1-800-332-2717 EXT.17

digital™

FPGA DESIGN-VERIFICATION ENVIRONMENT

which you can build other variants. You can model variants with differences, such as complemented clock inputs or missing clear signals, simply by including the basic model inside the variant model and complementing the clock input or tying the basic model's clear signal inactive.

You must determine exactly how many timing-parameter checks make sense for your application. For example, many single-clock synchronous designs have a synchronized global reset connected to their flip-flops' asynchronous-reset inputs. These designs use this reset line only once upon power-up. In these cases, the flip-flop model needs to check only the setup time between data and clock. The model can probably safely ignore parameters such as clock pulse width and reset recovery time. This limited checking can simplify the model. The model in **Listing 2a** checks only setup and hold times. If a setup or hold time is violated, the model prints a violation message to the simulator's screen.

Another important issue is reset behavior. Some FPGAs require that you explicitly route an asynchronous reset signal to each flip-flop that needs to be reset. For those devices, you can save resources by resetting only flip-flops that need resetting and permitting other flip-flops to decay to a quiescent state after some number of clock cycles has elapsed.

In designs of this type, the time required to reach the quiescent state may be too long to simulate. You need some mechanism that allows the simulation to leave the reset critical flip-flops in an initial unknown state at the beginning of the simulation and initializes the noncritical flip-flops to avoid having to wait for them to settle to their quiescent state.

The model in **Listing 2a** declares its *q* output as an *inout*, meaning that changes of state due to external forcing of the output by the simulator are visible to the model. The initial state of the *q* output is "*W*", or a weak unknown, that *will* drive an unknown state if such driving is important to the simulation. If such driving is not important, you force the flip-flop's *q* output to the desired state at the beginning of the simulation script, and the *if* statement at the beginning of the model detects the force and accepts whatever state you have forced for the driven *q* state.

The model also propagates a zero if an "X" or unknown is clocked into it. This action prevents an unknown flip-flop state from propagating to other flip-flops in your design and then consuming an inordinate number of clock cycles for the unknown states to decay away. Such behavior provides little value in design verification, and this tradeoff can save much simulation time with little loss of fault coverage.

Listing 2b shows an invocation of the flip-flop, using the

LISTING 4—SELF-SCHEDULING RAM MODEL

```
entity ram is
     port (
          d : inout std_logic_vector(15 downto 0); -- data
          a : in std_logic_vector(14 downto 0);    -- address
          ceN : in std_logic;                      -- chip enable
          .
          .
          .
     );
end;

architecture sequential of ram is
     signal s : boolean;                          -- self schedule
request
     type memory is array (0 to 32768) of integer;
     variable ramdat memory;
     .
     .
     .
     process (a,d,ceN,...,s'TRANSACTION)          -- sensitivity list
          variable ce : std_logic;                -- ce logical value
          variable tmp : std_logic_vector(31 downto 0); -- VHDL
     begin
          if a'EVENT then                         -- address line
changes
               s <= '1' after tACC;
          end if;

          if ceN'EVENT then                       -- chip select
changes
               s <= '1' after tCO;
          end if;
          .
          .
          .
          ce := not to_x01(ceN);

          -- valid read access

          if not a'EVENT and now-a'LAST_EVENT >= tACC and
               not ceN'EVENT and now-ce'LAST_EVENT >= tCO and ce = '1'
         then
               if not is_x(a) then
                    tmp := to_x01(ramdat(to_int(a)));
                    d <= tmp(15 downto 0);
               else
                    d <= "XXXXXXXXXXXXXXXX";
               end if;
          end if;
     end process;
end sequential;
```

THE SIMULATION-VS-PROTOTYPING TRADEOFF

The first revision of an FPGA usually still has bugs in it, even after simulation. Ten seconds of real time in a functional system can easily be worth days of simulation time. Bugs that show up only in the real world don't mean that design verification is pointless, though. Simulating a design up to some judiciously chosen point can uncover bugs that would take longer to find in an actual prototype.

You must base your choice of much verification to do with a simulator and how much to leave to actual hardware debugging on an analysis of the cost in verification time vs the benefit in debugging time. Design verification should attempt to probe those areas in your design where the greatest questions about your design's integrity exist.

For example, interfaces between microprocessors and static memory are straightforward. Compared to large blocks of custom control having complex state sequences, memory interfaces need little attention.

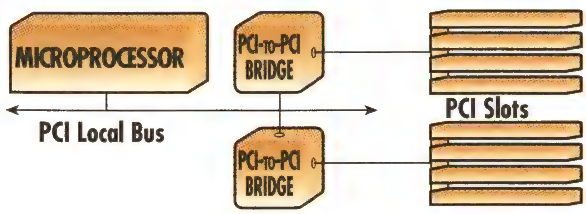
The law of diminishing returns applies to design verification. If a simulation makes your design's most basic and frequent operations visible, you can consider your design to be 50% covered. If the simulation exercises all state sequences, then a typical design is probably more than 90% covered. But, as coverage increases, each successive increment requires more effort and simulation time. Soon, you reach the point where leaving the last amount of coverage to actual operational test and diagnostic software is more economical.

A simple plan would be to first write simulations that exercise all state sequences. Then, spend some time developing simulations that generate asynchronous stimuli for your design. The exact tradeoff between preprototype and postprototype verifying depends very much on your design and judgment.

EMICONDUCTORS FROM DIGITAL

EXPAND YOUR PCI OPTIONS WITH OUR NEW PCI BRIDGE CHIP.

Is your design sidetracked by PCI load limits? Let Digital Semiconductor's new 21050 PCI-to-PCI Bridge chip get things rolling. It's the only PCI-to-PCI bridge available today. And it frees you from PCI loading limits for good. Motherboard designers can use it to implement as many PCI slots as they will ever need. Expansion card designers can use it to add multiple PCI components – for highly integrated multimedia, RAID, and LAN designs. It's easy. It's powerful. It's from the company that invented PCI-to-PCI bridging.



Call Digital Semiconductor for more information about our PCI Bridge and our other PCI chip products. Then get ready to open up some new territory.

CALL 1-800-332-2717 EXT.18

digital™

VHDL DELAYED construct for signal-wire delays. The VHDL GENERIC clause passes back-annotated timing parameters for the flip-flop into the model.

Proving that this flip-flop model does not behave exactly like an actual circuit is easy. The model trades robust behavior for shorter development time. Although less robust, the model remains quite usable for design verification. A useful model does not need to be precise in every detail. You can save a significant amount of time if you identify just how complex a model's behavior must be for your application and then implement only to that level.

Microprocessor model

Frequently, design verification requires a microprocessor model that exercises a slave device and accesses the device using varying timing, addresses, and data patterns. **Listing 3** shows a model for a microprocessor that reads access commands sequentially from a command file, *mp.dat*. Each command line of the command file contains a read or write indicator, an address, and optional data. For legibility and documentation's sake, the model permits blank lines and comments beginning with "#." The results of each read also get printed to the simulation console.

At the top of **Listing 3** are specifications for all of the timings for the model in symbolic form. You could code these times directly into the listing where they are used, but the result is not as readable, and changes to the timings are more difficult to make. In general, using this kind of symbolic abstraction to improve the readability and maintainability of a model is a good idea.

At the beginning of each command line that the model reads from the command file is a clock-cycle number. The model uses these numbers to time accesses. The model counts clock cycles and, when the requested clock cycle occurs, performs the specified access. Accesses wait for an acknowledge on the *ack* signal, timing out if no response occurs.

This microprocessor model demonstrates the power of behavioral models for design verification. A sequential program simulates the behavior of the microprocessor. Writing a state-machine implementation of the microprocessor model is much more difficult to do than writing the behavioral model in **Listing 3**.

RAM models

Often, simulations need RAM. The complex timing behavior of RAMs makes a robust RAM model a valuable tool in timing simulation. Proper RAM operation involves meeting numerous setup-and-hold specifications that make a typical RAM model fairly large. A usable static-RAM model that performs timing-violation checks can be 300 lines or more in length.

Although reproducing a RAM model in its entirety is beyond the scope of this article, there are some important points about RAM-model coding to consider. First, you can save simulation time if the model initializes itself from a data file upon simulation start-up and uses file I/O similar to the microprocessor model's.

Second, simulators usually incorporate a sensitivity-list mechanism that tells the simulator explicity which signals cause execution of a model when they change. In the case of the AND/OR gate in **Listing 1a**, the model executes each time one of its inputs, *a*, *b*, or *c*, changes.

Using specialized model scheduling can produce a mini-

COMMERCIAL MODELS EXHIBIT GOOD POINTS, BAD POINTS

For a price, third-party models are available for microprocessors, memories, and other functions. You could incorporate them in your design-verification environment. When considering commercial models, you should review the following factors:

- Because of the vendor's time dedicated to developing these models, you can reasonably assume that they are more robust than a simulation model that you have written. If the model is a complex one—for example, a bus-snooping microprocessor model—your effort to produce an accurate model from scratch may outweigh the cost of the model. Such a model may require a design verification before you can use it. Models that you code are not a capital investment. The only cost involved is design time, and for models of limited complexity, the time investment is not large.
- Commercial models may not suit your task. The set of all possible models for all possible parts will never exist, so, if you use commercial models, you need to make compromises in your verification environment. These compromises may translate into inefficiency or ineffectiveness.
- A commercial model may be more than you need, given its cost.

For example, you might need a FIFO model that is only 13 bits deep, prints a message on overflow, and centers its write pointer when overflow occurs. A commercial model is probably unable to meet these exact requirements.

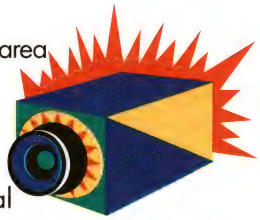
On the other hand, a commercial microprocessor model could accurately simulate instruction prefetch, caching, and other complex behavior. But you may need a model that drives only the address and data lines, toggles a strobe, then waits for an acknowledge. In this case, given the simplicity of a model you could code, the cost of the more complex model may not be justified.

Model vendors must provide as many options as possible, but the question remains whether you can optimize a commercial model to meet all the requirements of an efficient simulation. If you have total control of the model's source code, no such question arises. You can adapt your own model in the finest detail to the needs of your design-verification environment.

You may also wish to simulate a simple piece of discrete glue logic without having to purchase an entire library of 7400-series TTL models. You could accomplish this task in very few lines of a modeling language at virtually no cost.

MAXIMUM SECURITY.

With **LonWorks**® technology, you can get the lock on intelligent distributed security solutions. Developed by Motorola and Echelon Corporation, LonWorks technology provides secure local access control and easy methods of connecting your security system to telephone and computer networks for wide area monitoring. It can also link security systems to HVAC, lighting, fire control and elevator systems from different manufacturers to enhance overall safety and security. Personal devices that enable wireless access control, alarm activation and cashless purchasing can also benefit from LonWorks technology. Each component in a LonWorks network is driven by a Neuron® Chip, a powerful semiconductor with built-in operating system software and an embedded algorithm called Authentication.



Authentication uses a 48-bit key and a non-reversible function to verify that the initiator of an action is authorized by the receiver. This level of security requires two-way communications that other solutions do not offer. And LonWorks technology saves you installation time and money by supporting different network media, such as twisted pair, infrared, power lines, coaxial and RF. For security system OEMs and integrators, LonWorks technology is the smart — and safe — choice for control networking.

649 EDN 11 10 94

MAXIMUM RESPONSE. For quick delivery of a complete package of LonWorks technology literature, just fax the coupon below to **(800) 492-9384**, or mail it to Motorola, LonWorks Technology Center 616 W. 24th St., Tempe Ariz. 85282.

Name ______________________

Title ______________________

Company ______________________

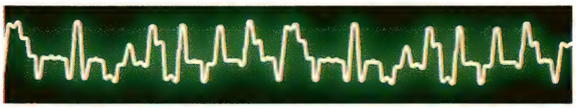
Address ______________________

City ______________ State ______ Zip ______

Telephone (___) ______________ Ext. ______

FAX Number (___) ______________________

Application ______________________



Coming through loud and clear.

MOTOROLA

MOS Digital-Analog Integrated Circuits Division

mally complex, understandable model. Simulators usually incorporate a scheduling mechanism that models delay. For instance, if a model contains the statement

a <= b AFTER 20 nsec;

the simulator schedules a change on signal *a* 20 nsec after each change on signal *b*.

For a part with as many signal-to-signal timing constraints as a RAM, an effective way to test for timing violations is using self-scheduling. Self-scheduling uses the simulator's scheduling mechanism along with the sensitivity-list mechanism to permit the model to schedule a timing check after an input transition. Self-scheduling causes a model to reschedule its own execution after the transition of a signal of interest.

To perform self-scheduling, the model declares a dummy input/output signal in its sensitivity list only for scheduling purposes. When the model must schedule an execution, it simply makes an assignment to that signal using either an AFTER clause or its equivalent. Because the signal is on the sensitivity list, the model re-executes after the specified time.

Self-scheduling is particularly useful when a model's input signals must statisfy multiple time constraints before an output signal becomes valid. RAM read accesses are such a case. Consider a RAM with an output that is valid subject to address access time, *tACC*, and chip-enable access time, *tCO*. **Listing 4** shows portions of a RAM model that validate both of these times using self-scheduling. For simplicity's sake, the example disregards other signals and timing parameters for the RAM.

In the upper part of the *process* in **Listing 4**, changes on the address and chip-select lines cause the model to reschedule an evaluation after *tACC* or *tCO* has elapsed. At that time, the lower part of the model validates a read access by checking to see if the access times have met *tACC* and *tCO*.

The TRANSACTION attribute specified for the scheduling variable in the sensitivity list causes model evaluation whenever the simulation makes an assignment to the scheduling variable, whether or not the variable changes state. Unlike the mechanics of common programming languages in VHDL, making an assignment does not necessarily change the state of a VHDL variable. VHDL can recognize an assignment even if the assignment has no physical counterpart in a real system. A variable with a "1" state, however, retains that state if it's assigned the value "1."

Note: The model may require some modification and work to get it to function as intended. For example, some VHDL simulators do not handle the LAST_EVENT attribute in the way that you might expect. In the actual RAM model (see **Listing 4**), I had to emulate the LAST_EVENT attribute in VHDL to produce the desired function.

Also, in the simulator I used, the TRANSACTION attribute did not always schedule re-evaluations as it should have. To work around this problem, I declared the scheduling variable as an array of type *boolean* and sequentially made rescheduling assignments to each of the elements in the array in a rotating fashion. Simulators are not without bugs.

RAM models are the most difficult of the models discussed in this article to write. If robustness of the RAM model is critical, you may need to build a small simulation to verify the RAM model before using it in design verification. If you are not relying on the model for timing verification, seeing the model work properly in your design-verification environment can be sufficient proof of its integrity. I use the second approach in conjunction with a static-timing analysis to yield a functional product with no known RAM-timing problems.

LISTING 5—TEST-CASE-DEPENDENT OSCILLATOR MODEL

```
library ieee;
use ieee.std_logic_1164.all;

entity osc is
 port (
          testno : in integer;            -- test number controls
behavior
                clock : inout std_logic := '0'
    );
end;

architecture sequential of osc is
       constant tCLK  : time := 100 ns;                   -- normal clock
period
begin
     process (clock)
         variable tCLKx : time;          -- calculated clock period
      begin
           if testno = 2 or testno = 6 or testno = 11 then
                 tCLKx := tCLK/2;
                else
                    tCLKx := tCLK;
          end if;
         clock <= not clock after tCLKx/2;
       end process;
end sequential;
```

Static-timing analysis

In general, timing simulation does not guarantee that a design meets timing requirements. Producing a simulation that exercises all the paths in a design can be a challenging task, especially if a synthesis tool produces the gate-level netlist. If you have produced models with timing checks in them, at least some of the checks will contain bugs that permit timing violations to go unnoticed.

In the type of design-verification environment described here, you should use timing simulation only as a reinforcement to timing verification using a static-timing-analysis tool. Static-timing analysis exposes all paths in a design, regardless of logic structure. A static analysis with an output that is used in a conscientiously prepared, hand-done, or spreadsheet-based, system-level timing analysis should expose any timing-check inadequacies in your design-verification models. Even if your models have no bugs, the thoroughness of a static analysis provides much more confidence in your design's timing than does timing simulation.

Design-verification techniques

Some general techniques that can make your design-verification environment more robust and efficient include global test numbering and software testing during simulation.

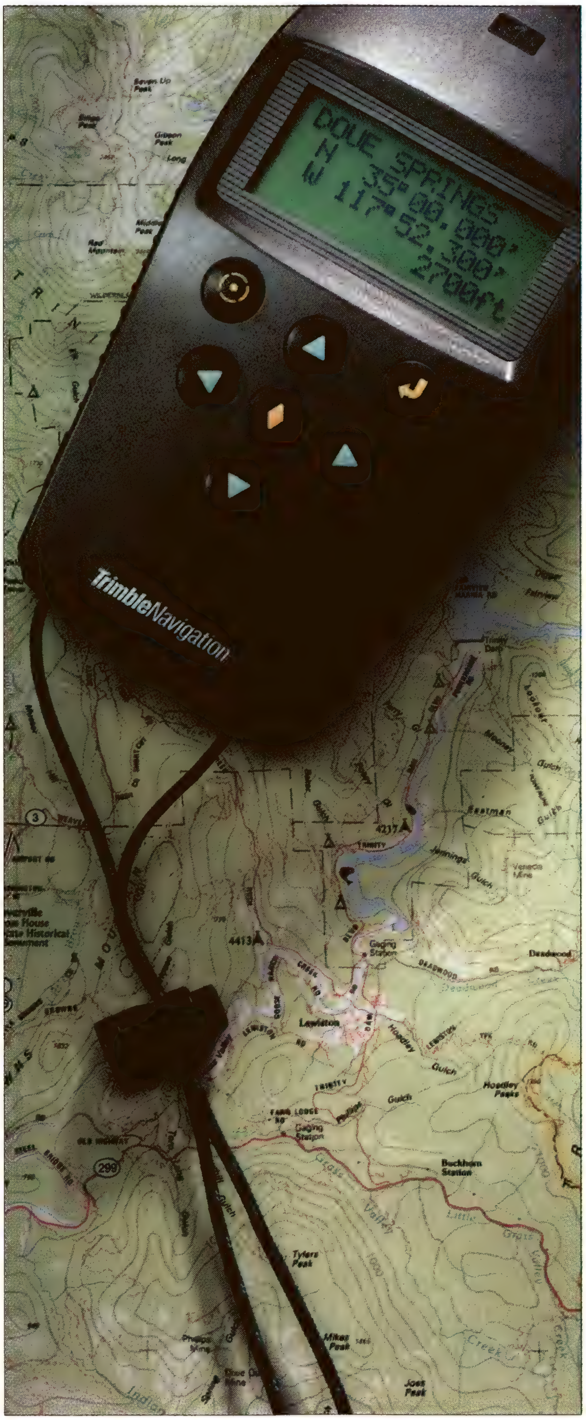
At the highest level, you should automate your test environment to make the most efficient use of your time. For example, suppose a model needs to change its function from test case to test case. You should consider writing the model to modify its function based on a test number connected to an input on each of the models in the simulation environment.

A simple example of this technique would be an oscillator that runs at twice the normal speed for certain test cases. **Listing 5** shows a model for an oscillator that does this for test numbers 2, 6, and 11.

The top-level netlist connects the *testno* inputs of all sim-

P-CAD HELPED PUT TRIMBLE ON THE MAP.

You're never lost when you carry the SCOUT GPS™ global positioning system from Trimble Navigation. P-CAD helped Trimble's design engineers find what they were searching for – the world's most productive PCB design software. Trimble used P-CAD software to navigate through the design process, cutting time to market and positioning their new product as a market leader. P-CAD PCB design tools enjoy some unique positioning of their own, consistently ranking first in pins-per-hour benchmark surveys among independent service bureaus. In fact, compared to other PC-based systems, P-CAD software helps designers do their work in as little as half the time. Take P-CAD Master Designer™ for example. It includes enhanced auto-dimensioning so designers can document



their work without mastering a separate mechanical CAD system. P-CAD offers a complete line of software tools for DOS, Windows™ and UNIX® platforms. For the name of your nearest P-CAD reseller, call or fax us today. And to help you map out your own winning design strategy, we'll send you a free copy of our booklet, *"P-CAD – Productivity Across the Board."* In today's competitive world, you could be lost without it.

France:
Tél: (1) 49 65 96 97
Fax: (1) 49 65 95 31

Germany:
Tel.: 0 69 / 6 64 00 80
Fax: 0 69 / 6 66 67 06

U.K.:
Tel: 049 445 9500
Fax: 049 445 9922

More Productivity — Across The Board

p-cad®

From ALTIUM, An IBM Company

CIRCLE NO. 161

STATEMENT OF OWNERSHIP

Statement of Ownership, Management and Circulation required by the Act of Congress of August 24, 1912, as Amended by the Acts of March 3 and July 12, 1946 and October 23, 1962 (Title 39 United States Code, Section 3685) of EDN® (USPS 074-090), published biweekly with one additional issue a month (38 issues annually) at 8773 South Ridgeline Blvd., Highlands Ranch, CO 80126-2329 for October 1994. Annual Rates: $120 US; $210 Surface; $182 Can.; $170 Mex.; $314 Europe Air Mail.

1. Names and complete addresses of the Publisher, Editor, and Managing Editor are:
   VP/Publisher, Jeff Patterson, 275 Washington Street, Newton, MA 02158.
   Editor, Steven Leibson, 275 Washington Street, Newton, MA 02158.
   Managing Editor, Joan Morrow Lynch, 275 Washington Street, Newton, MA 02158.
2. The owner is Cahners Publishing Co., A Division of Reed Publishing USA, 275 Washington Street, Newton, MA 02158.
3. The known bondholders, mortgages, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other security are: None.

Extent and Nature of Circulation

	Average No. Copies Each Issue During Preceding 12 Months	Actual No. Copies of Single Issue Published Nearest to Filing Date
A. Total No. Copies (Net Press Run)	153,438	170,073
B. Paid and/or Requested Circulation		
1. Sales through dealers & carriers, street vendors and counter sales	0	0
2. Mail Subscriptions Paid:	0	0
Requested:	146,000	165,040
C. 1. Total Paid Circulation	0	0
2. Total Requested Circulation (Sums of B1 & B2)	146,000	165,040
D. Free distribution by mail: samples, complimentary, and other free copies	2,605	2,869
E. Free distribution outside the mail: carriers or other means	0	0
F. Total Free Distribution (Sum of D & E)	2,605	2,869
G. Total Distribution (Sum of C1, C2 & F)	148,605	167,909
H. Copies not distributed		
1. Office use, leftovers, unaccounted, spoiled	4,833	2,164
2. Returns from news agents	0	0
I. Total (Sum of G, H1 & H2)	153,438	170,073
Percent Paid Circulation (C1/G x 100)	0%	0%
Percent Requested Circulation (C2/G x 100)	98.25%	98.3%

I certify that the statements made by me above are correct and complete. John Scheunemann, Distribution Manager.

FPGA DESIGN-VERIFICATION ENVIRONMENT

ulation models that are connected. The simulation script sets *testno* equal to the test number at the beginning of the script. This technique is preferable to editing and recompiling the model to change its behavior.

You can design your environment to use test-execution scripts at the highest level. These scripts select an entire set of simulation inputs, such as microprocessor access files and RAM data files, based on a single test number that is part of the test script's invocation. This technique provides you with more time to concentrate on the actual debugging of your design instead of the mechanics of simulation.

Another technique worth consideration involves joint testing of driver software and hardware. The driver software that manages the details of a design's operation often consists of a set of access routines and bit-field definition symbols, all of which you must debug. Rather than input all stimuli (RAM contents, etc) to your design in binary, you should construct the driver software so that parts of it may function as an application program if the appropriate compile switches are set.

This application program may then generate input data files for simulation using exactly the same symbolic constructs that the device-driver programmer uses. This approach has two advantages: You save the time and trouble of generating potentially lengthy sets of binary data to exercise your design, and the programmer is confident that his symbolic representation of your design is correct. Using symbolic representations instead of machine-based representations results in a net time savings. EDN

References

1. Unix *man page* for *awk* and *sed*.
2. GNU project documentation, Free Software Foundation, 675 Massachusetts Ave, Cambridge, MA 02139. (617) 876-3296. Or, via anonymous ftp over Internet: prep.ai.mit.edu:pub/gnu, files: COPYING, GNU, perl-*
3. "IEEE Standard VHDL Language Reference Manual," *IEEE*, March 1988.
4. Perry, Douglas L, *VHDL*, McGraw-Hill, New York, NY, 1991.

Author's biography

Leo Bredehoft is an engineer for Netrix Telecom Systems in Boulder, CO, and he has worked there for 3½ years. He specializes in digital and FPGA design, software, and diagnostic-software design. He has worked on telecommunications equipment, such as cross-connect and a time-division multiplexer. He obtained a BSEE from Wichita State University, Wichita, KS, and he is a member of Eta Kappa Nu, Tau Beta Pi, and Phi Kappa Phi. In his spare time, he enjoys playing classical piano and studying foreign languages.

VOTE

Please use the Information Retrieval Service card to rate this article (circle one):

High Interest 589 **Medium Interest** 590 **Low Interest** 591

PURE GENIUS

BP-1148

LIGHT YEARS AHEAD OF THE COMPETITION

The genius behind the new BP-1148 is its simplicity. You will discover that the BP-1148 is the most user friendly device programmer ever built. Now here's the smart part... for the first time anywhere, you can afford to buy a top quality programmer that will grow with your needs because you only pay for the device support you actually use. Go ahead. Show everyone how smart you are... put the BP-1148 to work on your next project.

- low cost upgradable programmers
- uncompromising quality and performance
- supports the latest and most complex devices
- thousands of algorithms available instantly
- pay only for the algorithms you actually use
- free software updates released each six weeks

1000 North Post Oak Road, Houston, TX 77055-7237
Internet: Sales.BPM @ notes.worldcom.com
Telephone (713) 688-4600

Sales & Technical Support 800-225-2102

BP MICROSYSTEMS

First In Support

CIRCLE NO. 113

Never lost a benchmark.
50% faster than anyone.
99.9% fault coverage.

(So good, it's embarrassing.)

In a time when superlatives are passed out like hors d'oeuvres at a party, we almost hesitate to tell you how hot our FastScan™ ATPG really is.

But here goes. FastScan, which is optimized for full-scan and scan-sequential designs, has not lost a single technical benchmark since it was first introduced nearly two years ago. Never. Not once. Also, it's 50% faster than the competition, achieves 99.9% fault coverage, and produces substantially less vectors.

All good reasons why FastScan, along with our partial-scan and non-scan FlexTest™ ATPG toolset, won a Best In Test award for 1993. And if that's not enough, they also provide full support for I_{ddq} test. And handle BIST and boundary scan designs.

Did we say boundary scan? Our BSDArchitect™ toolset can even automatically insert boundary scan into your HDL design at the HDL level. In either VHDL or Verilog.™ Your choice.

And all of our DFT tools work outside the Mentor Graphics framework as well as within. A true "plug and work" strategy. Made all the better by the outstanding performance of HP workstations. And HP MPower, which lets engineers join powerful productivity teams without ever leaving their desks. Mentor Graphics Corporation is a premier solution provider for Hewlett-Packard.

Phone 1-800-547-3000, dept. 338 for more information on Mentor Graphics' Full-Chip Test. Or E-mail dft_mgc@mentorg.com.

Mentor Graphics
We mean business.

HEWLETT® PACKARD

CIRCLE NO. 148

Verilog is a trademark of Cadence Design Systems, Inc.

Green strategies cope with electronic products' energy and end of life

JIM LIPPKE, CONSULTANT

Emerging design-for-environment techniques will help keep Mother Earth green.

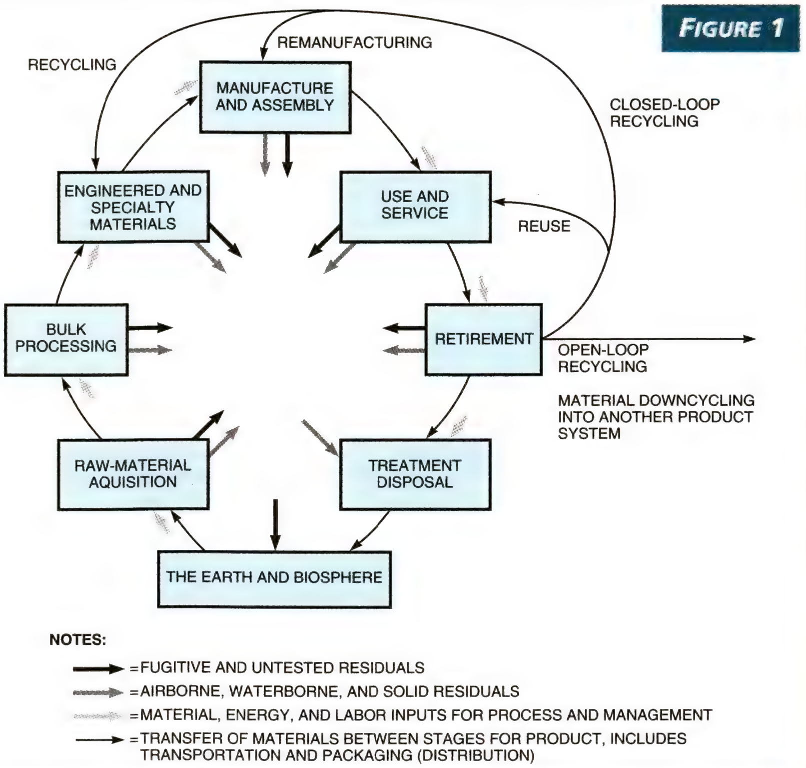
Engineers must be aware of the alternatives that make a system "green," but what are the guidelines for choosing the best options? Although design-for-environment (DFE) tools are available, they are at best crude. Engineers are "hampered by lack of comparative-risk information; lack of a method of comparing unlike risks; and a lack of a method for integrating risk, performance, and cost information into a decision-focused system," stated Jean Parker of the Environmental Protection Agency's Design for the Environment Program during the 1993 Electronics and Environment Symposium. Nonetheless, techniques are emerging to help make the right choices. Those techniques include life-cycle analysis (LCA), energy audits, pollution-prevention checklists, and guidelines for parts/material recovery and recycling.

LCA is a good starting point. The term refers to the overall process by which one evaluates all environmental impacts from acquiring raw materials, through manufacturing and use, to the final disposing of a product. In laying out the conceptual framework for LCA, James A Fava, a pioneer in the field, points out that the outlook in the '90s has moved beyond that of the '70s and '80s. The focus was once on constraining the discharge of pollutants into the air, water, and land. But in the 1990s, the EPA switched from pollution control to pollution prevention. The objective is to cut pollution to zero using natural ecosystems as the model. Industrial systems should not be open-ended, dumping endless byproducts, but closed, as nature is, cycling and recycling.

The practice of LCA stems largely from a basic text published by the Society of Environment Toxicology and Chemistry (SETAC) (**Ref 1**). *Technical Framework for Life-Cycle Assessment* states that companies can best begin LCA with senior management's commitment to improve the environmental quality of the company's products or manufacturing. This usually entails identifying the key functions associated with a product from R&D through marketing and sales to customer use and disposal. A team approach is necessary. Fava advises asking such questions as:

- What is the source of the raw materials?

FIGURE 1



The product life-cycle system is a closed loop that involves the earth and biosphere. Reuse, remanufacturing, and recycling can create other loops that counterbalance the system. (Source: EPA's *Life Cycle Design Guidance Manual*).

- Is the product highly dependent on nonrenewable resources?
- How much energy does the product use?
- Does the product's manufacture require highly energy-intensive processes?
- Does the product or process require extensive use of water?
- Are transportation costs high?
- Does manufacture or transportation cause excessive release of carbon dioxide?
- Can the product be easily recovered and recycled or reused?

A reference manual shows the way

The publication in **Ref 2** provides another basic LCA tool. **Fig 1** portrays that book's product life-cycle system, and **Fig 2** provides a schematic of life-cycle design. **Fig 3** depicts matrices to conceptualize environmental requirements and performance. In developing environmental requirements, first take stock of the materials used. **Table 1** lists factors you should consider, and **Table 2** lists how AT&T applies these principles in a demonstration project with the University of Michigan.

In its simplest form, LCA comprises three stages: taking inventory, assessing impact, and assessing improvements (**Fig 4**). Taking inventory, the most developed component of LCA, involves using a database that quantifies energy and raw-material requirements (inputs) and environmental outputs, such as air emissions, water effluents, and solid and hazardous waste for the life cycle of the product. Energy inputs can take into account transformation cost (raw materials into products), transportation cost (running assembly-line conveyers), and any reduction cost (when using recycled materials). Michigan State University has developed mathematical system models quantifying such inputs for given boundary limits.

Impact assessment is harder to perform. Certain materials, processes, or components may be toxic, but their impact on the environment and health varies, according to the amounts involved. For example, when evaluating a given design, you may have to decide what weights to give carbon-dioxide release compared with sulfur dioxide. If you use disposable or rechargeable batteries, how do you weigh performance (battery-charge life) against toxicity? You have to make and record value judgments so that others understand the basis for your rating.

Some companies are working to incorporate life-cycle costs and life-cycle cost-management calculations into LCA. One such company, Decision Focus Inc, Mountain View, CA, uses the Generalized Equilibrium Modeling System and proprietary CAD/CAE software. Another company doing economic modeling in DFE is Synergy International, Atlanta. Synergy provides "activity models" and reports that the US Air Force developed IDEF, a comput-

ENERGY STAR SAVINGS MOUNT

The Environmental Protection Agency (EPA) predicts that the demand for electrical energy will rise 1 to 1.5% per year through 2000. However, Dennis McGavin of Hewlett-Packard believes that residential energy demand could be 25% less if consumers bought energy-efficient appliances. Commercial and residential energy use is decreasing as manufacturers join the EPA's Energy Star, a voluntary program to induce manufacturers to produce more energy-efficient products. Energy Star logos appear on products consuming no more than 30W.

EPA estimates that manufacturers of laser printers, for example, could cut energy consumption 30 to 50%. The reduced consumption would save 6 billion kWhr in 2000, thereby reducing electricity bills by $500 million and avoiding annual carbon emission equal to that produced by 1 million cars. HP, a member of the Energy Star program, has four printer lines and the Vectra PC (including monitor) that qualify for a logo.

TABLE 1—ISSUES FOR DEVELOPING ENVIRONMENTAL REQUIREMENTS

	Materials	
Amount (intensiveness)	**Character**	**Impacts associated with extraction, processing, and use**
	Virgin	
Type	Recovered (recycled)	
Direct	Reusable/recyclable	Residuals
Product related	Useful life	Energy
Process related	Resource base factors	Ecological factors
Indirect	Location	Health and safety
Fixed capital	Locally available	
(Building and equipment)	Regionally available	
	Scarcity	
Source	Threatened species	
Renewable	Reserve base	
Forestry	Quality	
Fishery	Composition	
Agriculture	Concentration	
Nonrenewable	Management/restoration practices	
Metals	Sustainability	
Nonmetals		
	Energy	
Amount (energy efficiency)	**Character**	**Impacts associated with extraction, processing, and use**
	Resource base factors	
Type	Location	
Purchased	Scarcity	Materials
Process byproduct	Quality	Residuals
Embodied in materials	Management/restoration practices	Ecological factors
		Health and safety
Source		Net energy
Renewable		
Wind		
Solar		
Hydro		
Geothermal		
Biomass		
Nonrenewable		
Fossil fuel		
Nuclear		

(Source: EPA's *Life Cycle Design Guidance Manual*)

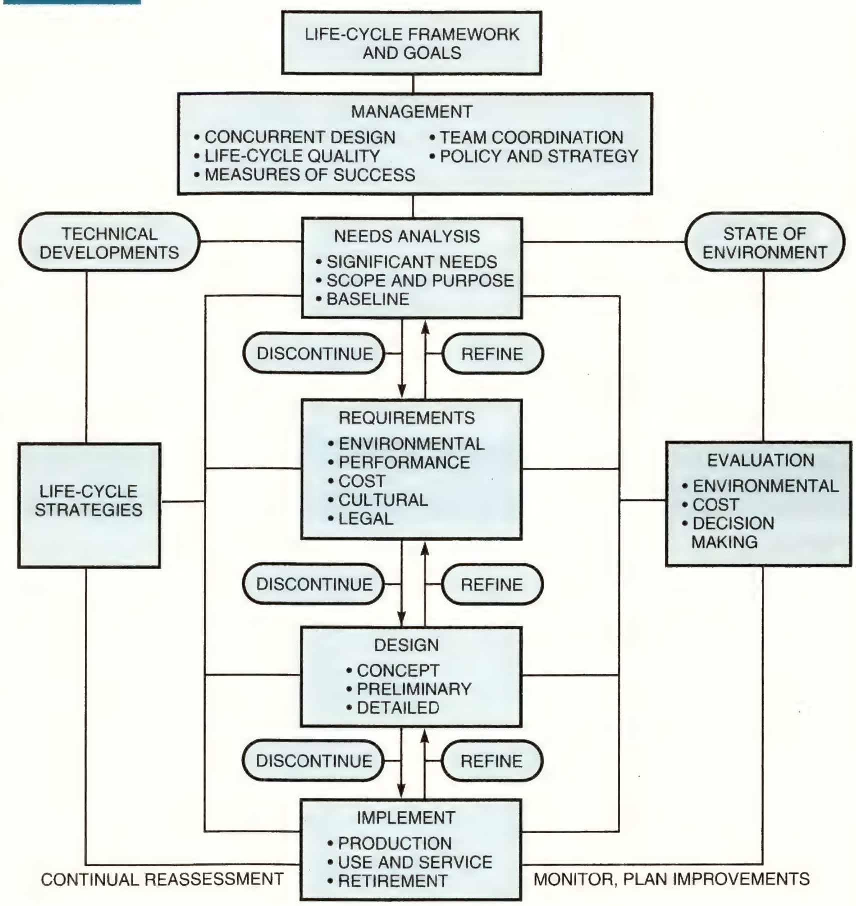
er-aided software-engineering tool, for defining complex sets of interacting activities in the life cycle of an aircraft.

LCA impacts electronics

Although LCA emerged to analyze manufacturing, particularly those involving toxic chemicals, it will soon affect all electronic sectors. The energy-efficient "green PC" is one example. Computers account for about 5% of all commercial energy in use today, and this may double by 2000, says Jacques Besnainou of Ecobalance (Wayne, NJ). "LCAs that encompass the entire life cycle of a product from raw-material extraction to end-of-life management alternatives (landfilling, incineration, and recycling) provide an unbiased map of industry systems." Besnainou says the reusable-vs-recycling and recycling-vs-incineration debates are complex and not as green as you might assume. For example, nickel alloy contacts in switches are not better than the more toxic alloys when you consider the total life of the switch.

The Life Cycle Center of the Technical University of Denmark, Lyngby, Denmark has made a detailed analysis of energy consumption for a frequency converter and a portable telephone. As Jens Legarth, an engineer at the Institute for Product Development at the University, told the 1994 Electronics & Environment Symposium, "Great rewards result from reducing energy consumption in *all* life-cycle phases." The Life Cycle Center maps and quantifies all environmental impacts from all life-cycle phases—raw-material extraction, production use, transportation, and customer use. Customer use of a product is the major contributor to smog, nitrogen oxides, acid rain, and carbon-dioxide release—all stemming from a product's energy consumption. Higher efficiency converters can reduce the impact.

FIGURE 2



Life-cycle design comprises a management strategy that oversees a continuously refined closed-loop system. (Source: EPA's *Life Cycle Design Guidance Manual*).

The Life Cycle Center normalizes all data by dividing it by a reference emission, based on the equivalent per-year per-world citizen. The Center expresses a product's contribution to global warming as a person equivalent. In the study of the portable phone, energy spent in production turned out to be greater than lifetime use, but the energy expended in production included that for not only material transformation but also the energy channeled to keep factory and headquarters workers comfortable (such as heating and air conditioning).

Switching power supplies generally operate at 75 to 80% efficiency, according to Charles Sullivan, an engineer and member of the computer department of the University of California at Berkeley. He believes that 95% efficiency should not be difficult to achieve. In any case, switching power supplies are superior to linear units, which are approximately 50% efficient and require expensive transformers and capacitors. He points out that you must consider the duty cycle of a product's power demands. Standby or idle power for a telephone-answering machine is greater than the power consumed during operation. In the design of portable computers, power management ranks in importance with computing capability.

Sullivan points out that you must consider full product-life—not short-term—power costs because the least expensive component for a job may be the most costly in the long run. For a 2.5A circuit requirement, a \$3.30 MOSFET overrated at 18A operating over five years has a total cost of \$6.29 compared with \$25.58 for a \$0.98 MOSFET that handles 2.5A. In another example, Sullivan determines that a line-powered electronic clock costing \$10 consumes nearly that much cost in electricity in 10 years. LEDs use more power than LCDs, he adds. Sullivan also suggests that there is considerable room for reducing clock power because no electronic timekeeping device on the market uses less than 10 μW.

If end-of-life products go into landfills, waste can never be reduced to zero. Western industrial countries are rapidly closing their landfills. US landfills will number 3250 by 2000, for example, compared with 18,500 in 1979. However, electrical

DESIGN-FOR-ENVIRONMENT TOOLS

and electronic products that need disposal are doubling. Germany is dumping 1 million to 1.5 million tons of used electronic products annually, with TV sets accounting for almost 60% by weight. A study in France, the Desgeorges Report, found that 1.3 million tons of electrical products are now reaching end of life. Nearly twice that amount is entering the market, so the problem of electrical waste is getting worse. Commercial/industrial electrical products account for 31% of electrical waste; appliances, for 29%; batteries, for 14%; consumer electronics and cable, for 8% each; computer office equipment, lighting fixtures/lamps, and "other," for 3% each; and telecommunications, for 1%. Computer waste is the growth factor. If things don't change, Americans could be dumping 150 million PCs by 2005, according to another study.

To cope with the waste problem, Europe has pending legislation that calls for manufacturers to take back the products they produce. Both the Netherlands and Germany are close to passing such laws. Computer companies are looking at the "six Rs" of DFE: reduce, reuse, reclaim, refurbish, remanufacture, and recycle. Take-backs add to the costs of products, but some companies, such as Digital Equipment Corp, Hewlett-Packard, and Xerox, see a potential cost benefit from recycled materials according to Dave Williams, a professor at Loughborough University in the United Kingdom, who interviewed these and other manufacturers.

HP is recycling 65% of its hardware in Europe, Williams reports. European Xerox "asset-recovery" activity reports for 1992 indicate that the company reprocessed 50,000 field-returned copiers to yield 755,000 components (51% by weight), and recycled 46% by weight into reusable materials.

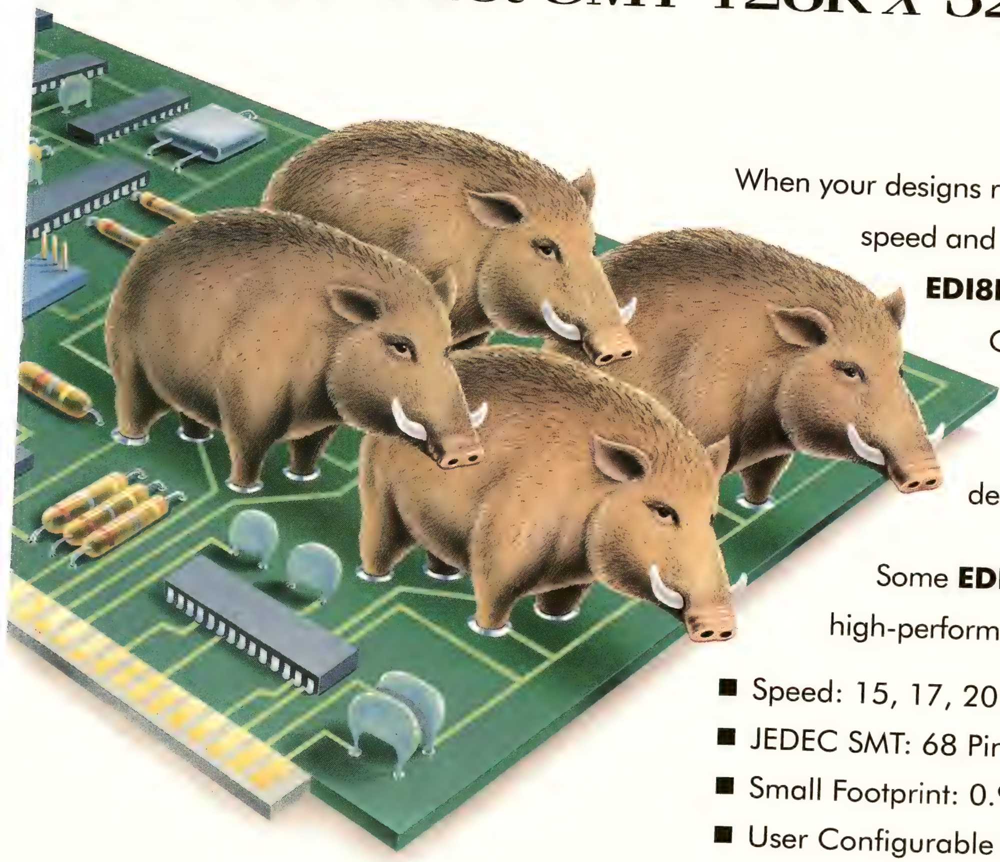
TABLE 2—ENVIRONMENTAL REQUIREMENTS

	Manufacture	Use/service	End-of-life management
Product	Materials should be recyclable (preferably on-site) • (plastic regrind) — Maximize use of recyclable materials when environmentally preferable — Choose ODS-free components — Eliminate the use of toxic materials, such as Pb	— Extend useful life through modular design with sufficient forward and backward capability — Make products upgradable • (ROM parts • sockets for additional memory or processor chips)	— Reuse parts (such as handsets and cords) — Standardize parts to facilitate remanufacture — Product components recyclable after consumer use — Open-loop recycling into fiber cables, spools, reels — Easy to disassemble: no rivets, glues, ultrasonic welding; minimal us of composites — Components easy to sort by marking and minimal use of materials — Housing should be shreddable
Process	— Minimize process wastes, including air emissions, liquid effluents, and hazardous and nonhazardous solid wastes — Minimize resource and power consumption — Meet five corporate environmental goals — Do not commingle waste streams	— Energy-efficient operation (operate on line power only)	— Maximize material recycling of components not reused — Service or reconditioning operations should minimize use of paints and sol vents — Minimize wastes, including air emissions, liquid effluents, and hazardous and nonhazardous solid wastes from refurbishing operations
Distribution	— Minimize supplier packaging • (nonhazardous) — Packaging containing recycled material (postconsumer content specified) — Reusable trays for parts in factory	— Minimize product packaging • (use Electronic Packaging Guidelines • (nonhazardous inks, etc) — Optimize number of phones per package — Specify packaging containing recycled material (postconsumer content specified) — Use recycled paper for manual — Minimize material variety for packaging	— Use reusable shipping containers — Use recyclable packaging — Use packaging containing recycled materials
Information management	— Use design-for-environment (DFE) tools — Encourage suppliers to discontinue use of ODS in parts manufacturing	— Print manual on recycled paper (list environmental features) — Print recycling instructions on product packaging	— Supply toxic-material content — Provide product-recycling instructions — Provide product-disposal instructions

(Source: AT&T)

Beat The Board Hogs

With the First SMT 128K *x* 32Bit SRAM

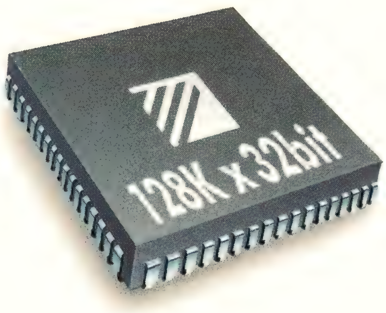


When your designs require more memory, speed and board space, the new **EDI8L32128C-AC** is the answer. Our high density memory array solution doubles the efficiency of your board design - in *half* the space.

Some **EDI8L32128C-AC** high-performance advantages:

- Speed: 15, 17, 20 and 25ns
- JEDEC SMT: 68 Pin PLCC
- Small Footprint: 0.990 sq. inches
- User Configurable Organization
- High Density 4 Mbit CMOS SRAM

Achieve the greatest memory efficiency without hogging your valuable board design. Give us a call today for samples and application information.



Better performance than four 128K x 8 PSOJs in half the space

New Memory Databook now available.

508-366-5151 ext. 214

EDI is ISO9001 Certified

EDI
ELECTRONIC DESIGNS INC.

Electronic Designs, Inc.
One Research Drive • Westborough, MA 01581 USA Tel: 508-366-5151 • Fax: 508-836-4850

Electronic Designs Europe, Ltd.
Shelley House, The Avenue • Lightwater, Surrey GU18 5RF United Kingdom • 0276 472637 • Fax: 0276 473748

CIRCLE NO. 122

This left only 3% of the parts for disposal. Strategies to cope with end-of-life recovery point to a major paradigm shift for OEMs, according to Ray Dirby and Dewey Pitts of IBM (Research Triangle Park, NC). Designers must adopt upgradable modular-design approaches. Yvon Marty, Alcatel (France) points out that "recycling must be embedded into product design."

During the 1994 E and E Symposium, Thomas Porada of DEC called material recovery "asset alchemy." To recover valuable assets, the company has set two major programs, the Digital Idle Asset Listing (DIAL) and the Resource Recovery Center. Policy requires that departments should review DIAL before requesting new capital equipment. The policy has saved the company millions of dollars in equipment annually, says Porada. At the recovery center, DEC can sell recovered solid waste and process hazardous waste that the recovery processes generate. Without revealing quantities or dollar values, Porada describes DEC's own list of the six Rs: reuse (internally) 1.4% recovered; resale (equipment, components), 23.2%; refurbish, 1.4%; remanufacture, 0.3%; reclaim (printed wiring boards, ICs, cables, and connectors) 6.7%; recycle (metals, plastics, paper, and CRTs) 54.9%. Porada says the waste-to-energy conversion has been 12%. Hazardous landfill was less than 1%. Before disassembling materials, DEC carefully identifies proprietary components to prevent them from entering the market. Some high-value components are finding their way into toy markets via brokers, Porada says.

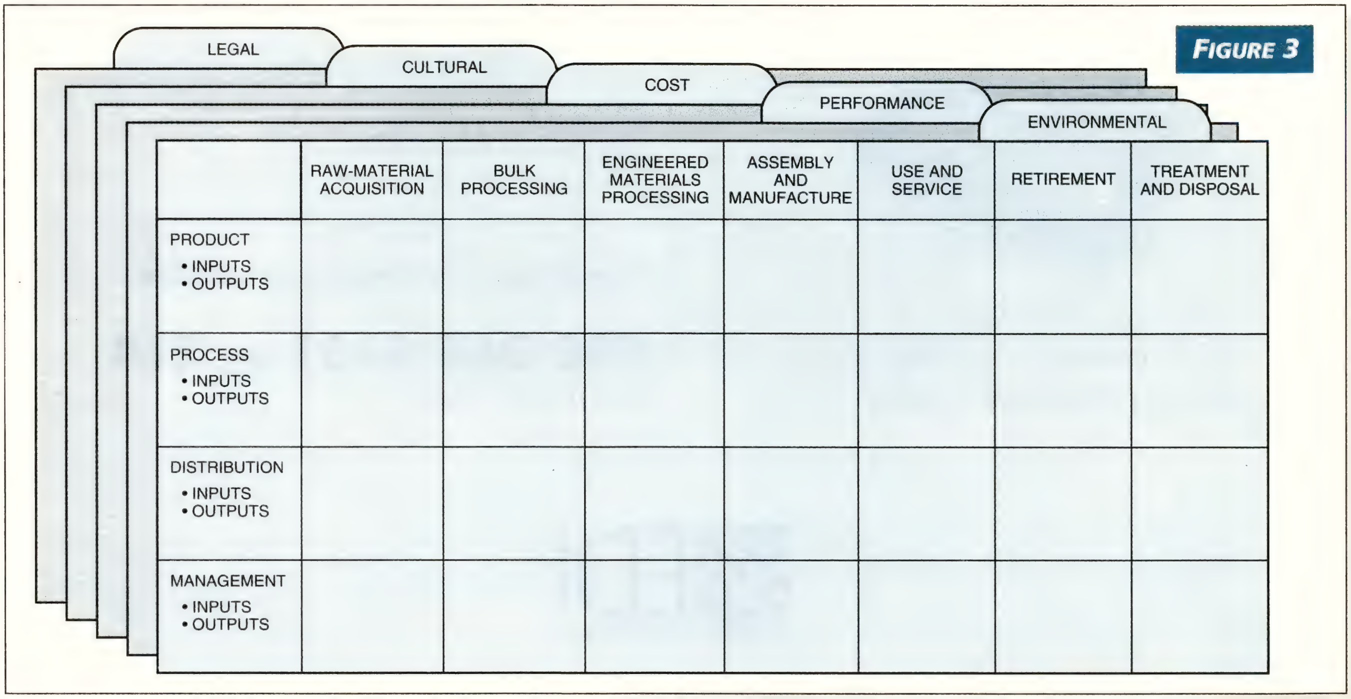
Identifying all materials used is the key to easier recycling; all plastic parts must carry recycling symbols. Making parts from fewer material types and reducing paints, platings, and screws also aid in recycling. At Sony Europa (Fellbach, Germany), ideas for the reusability of electronic modules include more modularity and the storage of identification data within the module accessible through a so-called "green port." This data can also include life-history information for reuse decisions; identification ICs could store information about additives, fillers, and flame retardants in plastics, which hinder recycling.

Design for disassembly (DFD) will be a major requirement of DFE in applying the Six Rs as product take-backs increase. Researchers at Darmstadt University of Technology in Ger-

SHOULD WE RECYCLE OR DUMP BATTERIES?

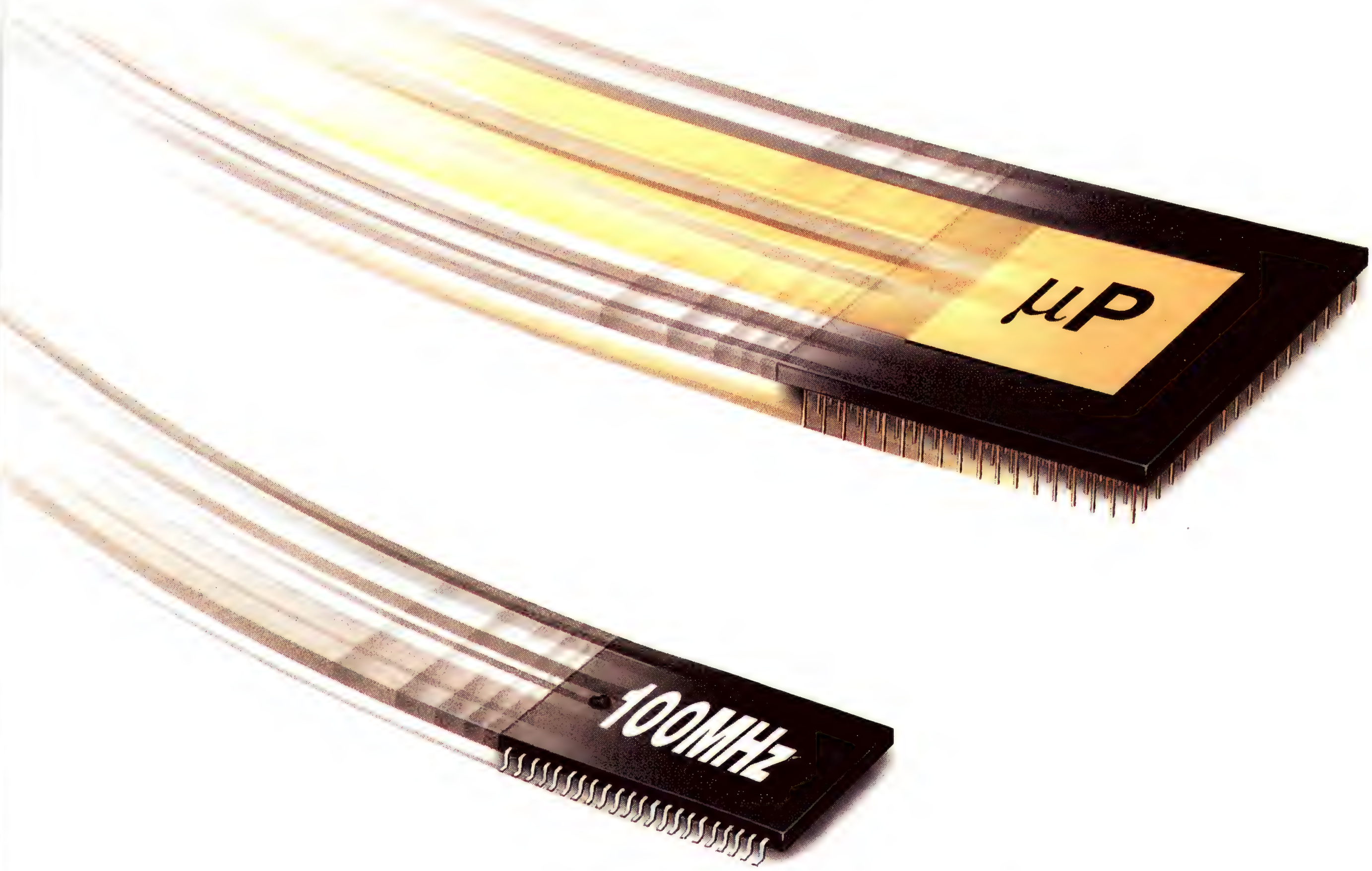
Every laptop computer user who discards dead batteries adds to the environmental problem. Of the dozen or so battery-cell types available, ranging from low specific energy (40 Whr/kg) to Lithium/polymer types (200 Whr/kg), all contain a high portion of toxic materials. Although government regulations prohibit putting lead-acid batteries into municipal waste, consumers regularly discard NiCd and nickel-metal hydride (NiMH) batteries, which are popular in laptops.

Because of the annual sales of 10 million portable computers, environmental engineers at Carnegie Mellon University, Pittsburgh, estimate that consumers will purchase 15 million battery packs annually, which represents 7700 tons of batteries. Assuming the replacement of two sets of batteries over a five-year period, that means we must dispose of 35 million units, or 17,500 tons, of toxic waste each year. Collections for household hazardous waste costs as much as $10,000/ton, and bulk disposal of rechargeable batteries by the Department of Defense costs $2000. Returning batteries to their manufacturer costs $2/lb in shipping and handling plus a bulk-disposal fee, making the cost $5000/ton.



Conceptual-requirement matrices comprise tables of inputs and outputs vs manufacturing processes that affect them. (Source: EPA's *Life Cycle Design Guidance Manual*).

As fast as your microprocessors:



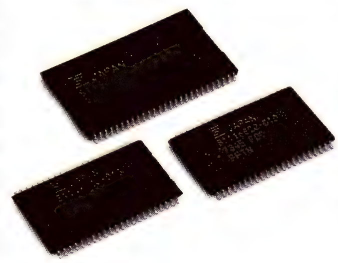
Synchronous DRAMs from Fujitsu.

If you're using expensive SRAM cache memories because you can't find DRAMs to match your fastest microprocessors, your wait is over.

High data transfer rates

Fujitsu has the DRAMs you've been waiting for: Synchronous DRAMs (SDRAMs) with speeds up to 100MHz and data transfer rates up to 100Mbytes/second. They operate synchronously with your processor clock, simplifying system control.

System design is simple, too. Fujitsu SDRAMs conform to JEDEC standards and they require only 3.3V power (± 0.3V). This makes them the perfect choice for multimedia PCs — even low-voltage notebook models — and for most workstations and high-performance systems.



Replaces high-priced VRAMs

Fujitsu SDRAMs also make excellent replacements for VRAMs in many graphic systems. Less expensive than VRAMs, SDRAMs also eliminate the need for two data bus systems between the display controller and the RAM.

World's first 64Mb SDRAMs

Our 16Mb SDRAMs are available now in production quantities, with 4Mb units available soon. Engineering samples of our 64Mb SDRAMs — the world's first — will be available by the end of the year. So why wait? For complete specifications, call Fujitsu today.

FUJITSU

COMPUTERS, COMMUNICATIONS, MICROELECTRONICS

Headquarters (Japan): FUJITSU LIMITED (Electronic Devices International Operations Dept.) 1015, Kamikodanaka Nakahara-ku, Kawasaki 211, Japan Phone: (81-44) 754-3753 Fax: (81-44) 754-3332
North America: FUJITSU MICROELECTRONICS, INC. 3545 North First Street San Jose, CA 95134-1804, USA. Phone: 408-922-9000 Fax: 408-432-9044, 9045
Europe: FUJITSU MIKROELECTRONIK GMBH Am Siebenstein 6-10, 63303 Dreieich-Buchschlag, Germany Phone: (06103) 690-0 Telex: 411963 fmg d Fax: (06103) 690-122

CIRCLE NO. 123

many are exploring automatic disassembly of products through the use of a robot. Although they are still in the first stages of investigation, the researchers have accomplished complex disassembly. They are now investigating additional actuators and tools, and the next step is to integrate artificial-intelligence approaches. The Institute of Manufacturing Automation and Production Systems, Erlangen, Germany, is conducting longer term research that may lead to the analysis of printed wiring boards. The use of surface-mount components will win out over components with bent and soldered lead through holes, and companies will use adhesives less. Disassembly without destruction is the goal. EDN

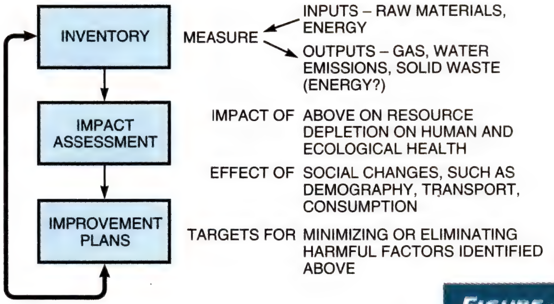


FIGURE 4

LCA comprises three interacting stages: inventory, impact assessment, and improvement plans. (Source: Ken Snowden, BNR Europe)

References

1. *Technical Framework for Life-Cycle Assessment*, The Society of Environmental Toxicology and Chemistry, 1991.

2. Keolian & Menerey, *Life Cycle Design Guidance Manual*, EPA/600/R-92/226, National Pollution Center, University of Michigan.

Author's biography

Jim Lippke is a managing partner of Sustainability Concepts, Solutions, a consulting company, where he has worked for three years. In his current position, he studies energy, economic, and employment issues and how to reduce energy usage and pollution. Jim has a BSEE from the University of Minnesota and is a member of the IEEE. He lists his main interest as being a mirror to the illuminating insights of others.

Acknowledgement

Most of the sources for this article stem from the 1993 and 1994 Electronics and the Environment Symposia.

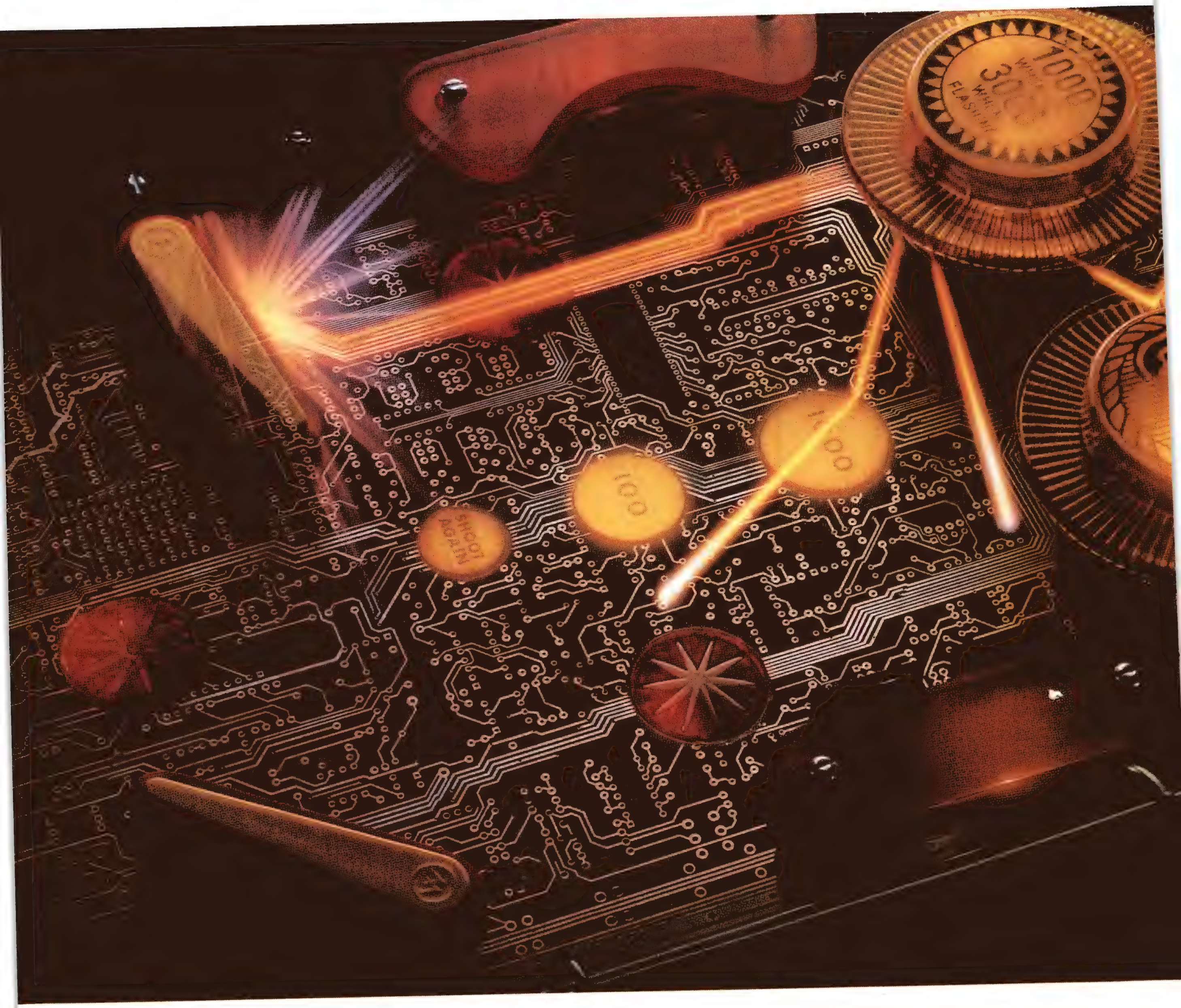
VOTE

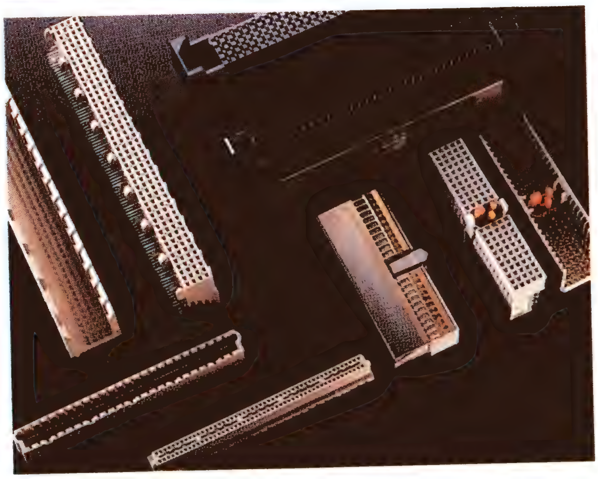
Please use the Information Retrieval Service card to rate this article (circle one):

High Interest	Medium Interest	Low Interest
586	587	588

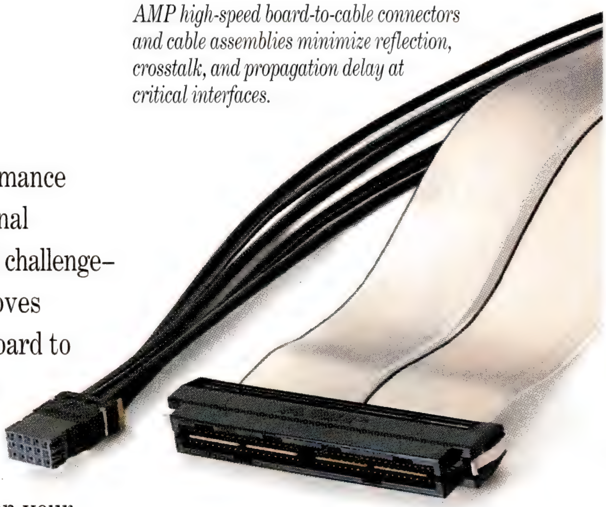

Check Out the Standard in Power Components
ISO 9001 Certified
Worldwide Agency Approvals
Largest Selection of Input/Output Combinations in the Industry
Over 2.5 Million Modules in the Field
1-800-735-6200
Test Report
Applications
VICOR
CERTIFICATE
Recognized Component
Directory
Component Solutions For Your Power System
Vicor Corporation 23 Frontage Road, Andover, MA. 01810 USA • TEL: (508) 470-2900 • FAX: (508) 475-6715
Vicor GmbH Carl-von-Linde Strasse 15 D-85748 Garching-Hochbruck, Germany • TEL: +49-89-329-2763 • FAX: +49-89-329-2767
Vicor Far East 6F- 3A, 293 - 3 FU-Hsing S. Rd. Sec. 2, Taipei, Taiwan, R.O.C. • TEL: +886-2-73643490 • FAX: +886-2-7337341
VICOR
CIRCLE NO. 212

At fast edge rates, the wrong interface takes on unexpected qualities.





AMP high-speed connectors – in hard metric, shielded hard metric, Futurebus, stripline, and microstrip versions – offer a broad range of signal management solutions.



AMP high-speed board-to-cable connectors and cable assemblies minimize reflection, crosstalk, and propagation delay at critical interfaces.

As the demand for performance pushes clock rates up, signal integrity can become a real challenge–especially when traffic moves from board to board, or board to cable. Interconnects that worked last time around suddenly act a lot like bumpers and flippers when your signal hits them. Fortunately, expert interconnect help is available.

We'll show you a broad range of technology solutions–the newest and best of subnanosecond interfaces. We'll work with you to choose the right combination of performance and features to meet tough circuit requirements. And our experience in design and in manufacturing can help make sure your choice works on the production line, as well.

Our high-speed and controlled-impedance interconnect solutions are engineered for hassle-free implementation, even with edge rates pushing 250ps. Our board-to-board selection includes high-density open pin field types (shielded versions available), plus stripline and micro-strip styles that allow you to match characteristic board impedances to minimize crosstalk, reflection, and groundbounce. Our board-to-cable selection includes precision miniature coax and transmission line offerings to maintain signal integrity with minimum propagation delay.

And we offer the simulation tools you need to confirm performance <u>in software</u>, before you build your first prototype. Talk with your AMP Sales Engineer today, or call; we're ready to help.

Scandinavia: Sweden 46-8-580-833-00 (fax 46-8-580-194-70)
Central Europe: Holland 31-73-20-0911 (fax 31-73-21-2365); Germany 49-6103-7090 (fax 49-6103-709223); Great Britain 44-81-954-2356 (fax 44-81-954-6234)
Southern Europe: France 33-1-34-20-8888 (fax 33-1-34-20-8600); Italy 39-11-401-21111 (fax 39-11-403-1116); Spain 34-3-200-8466 (fax 34-3-201-7879)

CIRCLE NO. 109

AMP

Philips Semiconductors **Update**

Digital video-to-PCI-interface IC puts Philips video capture technology on the PCI-bus

The SAA7116 YUV video-bus-to-PCI-bus interface chip permits instantaneous, live video display from any analog video source directly onto the graphics monitor.

The SAA7116 interfaces directly with Philips' existing family of digital PAL, NTSC and SECAM video decoder devices including the SAA7196, SAA7110 and SAA7151B. By combining the new device with the SAA7196, the video image can be scaled to any size on the screen, stored in a hard drive or sent to the CPU for compression, manipulation or processing before storage.

The SAA7116 buffers each frame of the video capture chipset's digital output before burst-mode DMA-transferring it over the PCI-bus. These data transfers can be direct to the PC's video RAM for live display of the captured video, direct to a hard disk for storage, or via the computer's CPU so that the video image can be manipulated or compressed.

Typical applications for the SAA7116, when used in conjunction with the video capture chipset, include PC-based multimedia computers and PC-networked distribution of real-time video sequences for education, training and information display.

The SAA7116 buffers and DMA-transfers the digital video data to any memory location on the PCI-bus at full resolution and frame rate.

Call 1-800-447-1500 Ext 1153
Europe: circle no. 40

For more information on any of these subjects: call 1-800-447-1500 and request appropriate extension number.

Europe – use EDN Information Retrieval Service or contact us direct via fax on +31 40-724825.

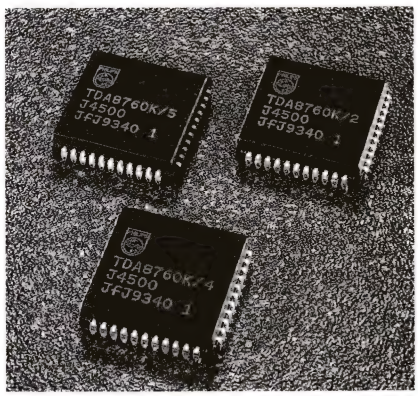
All Philips Semiconductors plants worldwide are ISO 9000 certified

High sample rate, high resolution, 10-bit A/D converter

The TDA8760 high-speed, 10-bit A/D converter is the first commercially-available monolithic ADC to combine 50 Msamples per second sampling with 5 V supply operation and power dissipation below 1 W (850 mW). The TDA8760 is designed for use in high-performance applications such as medical imaging systems, video cameras and satellite receivers. When sampling a 4.43 MHz full-scale input at 40 Msamples/s, it achieves a signal-to-noise ratio better than 56 dB and a THD (Total Harmonic Distortion) figure better than –65 dB.

The TDA8760's integrated sample-and-hold circuit has a 220 MHz –3 dB bandwidth capability. External reference voltages define the input levels corresponding to digital zero and digital full-scale so that the converter's input range can be adjusted to accommodate signal amplitudes up to 1.5 V pk-pk.

Packaged in a 44-lead PLCC, the TDA8760 has multiple 5 V supply pins to eliminate noise coupling between its analog and digital sections; separate multiple-pin analog and digital grounds prevent ground noise from affecting the digitization.



The TDA8760 10-bit A/D converter is available in three versions, with maximum sample rates of 20, 40 and 50 Msamples/s.

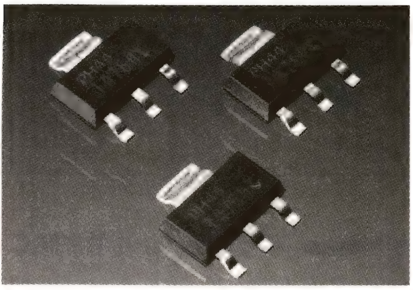
Call 1-800-447-1500 Ext 1154
Europe: circle no. 41

Philips Semiconductors

SOT223-packaged power MOSFET has full on-chip protection

Vith the introduction of the BUK107 logic-
evel TOPFET, Philips Semiconductors is the
irst company to offer a temperature and
overload protected 0.5 A low-side driver in a
SOT223 surface-mount package. The BUK107
s designed primarily for lamp, solenoid and
mall motor switching in automotive
applications such as engine management and
driver information systems, but its built-in
protection against short-circuit, over-
temperature and over-voltage conditions also
makes it suitable for a wide range of industrial
applications where high reliability is required.

The transistor is available in two versions, either with a logic level control input that can be driven directly from a microcontroller port, or with a clamped intput that can be used with a pull-up resistor drive circuit.



The BUK107 power MOSFET is the first fully-protected low-side driver to be offered in a true SMD package.

The BUK107 is a vertical DMOS power FET with an overload protection circuit that limits the drain current to typically 1 A, and an over-temperature protection circuit which senses the junction temperature to prevent thermal damage. In addition, integral over-voltage clamping diodes coupled with controlled turn-off of the FET limit the drain voltage to 50 V, allowing the BUK107 to be used for inductive load switching. No external protection components are required; all the active on-chip protection circuits are powered directly from the control input, so the BUK107 has an off-state current consumption of typically 1 μA at 50 V. The device is housed in a standard SOT223 package with all pins protected against electrostatic discharges.

Call 1-800-447-1500 Ext 5017
Europe: circle no. 42

Two new low-cost microcontrollers from 80C51-derivatives leader

With the introduction of the 8XC748 and 8XC749 8-bit microcontrollers, Philips Semiconductors continues to meet market demand for low-cost, small-memory-system microcontrollers. Both have a 16 MHz maximum clock frequency and 2 kbytes of program memory, while the 8XC749 also includes an on-chip A/D converter and PWM output so that it can perform analog I/O operations.

The 8XC748 and 8XC749 are targeted at a very broad spectrum of applications, ranging from toys and consumer products to industrial control and computing equipment. Their low power consumption and availability in SSOP packages make them particularly suitable for use in hand-held, battery-powered equipment. Philips Semiconductors is, in fact, the first company to offer 80C51-derivative devices in the miniature shrink small outline package.

Both microcontrollers are available in EPROM/OTP versions (87C748 and 87C749) and as mask-programmed versions (83C748 and 83C749). Their 24-pin and 28-pin SSOP packages have a height of 2 mm and PC-board footprints of 66 mm² and 82.2 mm² respectively – less than half the mounting height and footprint of other surface-mount 80C51-derivative microcontrollers packaged in PLCCs. The new microcontrollers are also available in DIP and PLCC packages.

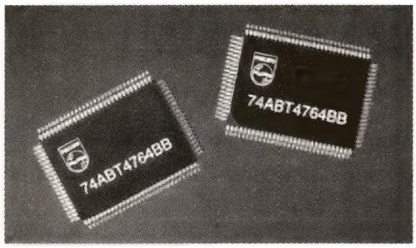
Philips Semiconductors' new low-cost microcontrollers are available in the miniature shrink small outline package (SSOP).

Call 1-800-447-1500 Ext 1156
Europe: circle no. 43

First fully-programmable BiCMOS DRAM controller for high-speed, dual-port memory systems

Combining the efficiency of a standard dual-port DRAM controller with the flexibility of an application-specific device, the new 74ABT4764 features an 80 MHz on-chip PLD sequencer that can be programmed to control high-performance memory systems. In addition to operating with any type of DRAM, the 74ABT4764 has the ability to interface directly to CISC processors, RISC processors and DMA channels without the need for glue logic, and to arbitrate memory requests from any two of these devices and the memory's refresh logic.

Equipped with 16 CAS (column address strobe) outputs, four RAS (row address strobe) outputs and an on-chip multiplexer for 11-bit memory addresses, the 74ABT4764 directly addresses up to 4 Mbytes of memory. This can be made up from DRAMs with capacities up to 16 Mbit (4M x 4), and, with the addition of a few inexpensive logic chips, the device can also address 64 Mbit DRAMs. Memory access modes include page, fast page, interleaved page, nibble and static column modes, with datapaths up to 8 bytes wide.



The 74ABT4764 fully-programmable BiCMOS DRAM controller offers exceptional flexibility.

The key to the 74ABT4764's exceptional flexibility is the on-chip PLD sequencer that controls the row/column address counters and multiplexer, the loop counter and an active page comparator that detects whether the current row address is within an active memory page. The counter overflow outputs and the hit/miss output of the active page comparator all feed back to the sequencer inputs.

The 74ABT4764 is manufactured in Philips' QUBiC BiCMOS process.

Call 1-800-447-1500 Ext 1155
Europe: circle no. 44

11/94/US

PHILIPS

Secondary cache increases performance and reduces power use in portable PCs

J THOMAS PAWLOWSKI, MICRON SEMICONDUCTOR INC

For some time, the main focus of portable-computer development has been to extend the computer's operating time on a single battery charge. Performance considerations were secondary. However, now that portable operation ranges to eight hours plus, the focus is shifting toward improving operating performance. The new challenge is to improve operating speed without sacrificing the gains in mobile operation time.

Secondary SRAM cache can increase system performance and reduce power consumption in portable PCs by varying degrees, depending on the system configuration. Copying a portion of main memory into fast SRAM increases the system speed by reducing the number of accesses to slower DRAM. System-design choices affect the cache efficiency and determine power consumption and performance. The choice of hardware and architecture that optimizes one software application may have a negative impact on other applications.

A performance and power analysis comparing the effect of cache on system designs can demonstrate the value of architectural choices. Although the variety and complexity of µPs, chip sets, and operating systems (OSs) make analysis difficult, the following example can provide an indicative comparison.

Performance and power analysis parameters

Our analysis employs a 486SX-33 with 4 Mbytes of DRAM, a common main-memory configuration. You can use 3.3V SRAM with 5V-tolerant inputs and outputs or 5V SRAMs when adding an external cache to a 5V CPU. Because the CPU is buffered from main DRAM, you can use 5 or 3.3V DRAMs with 3.3V CPUs. The analysis includes several combinations of cache and main memory to investigate the alternatives' sensitivity to supply voltage, cache-SRAM type, assumed internal and external cache-miss rates, and DRAM type.

At 33 MHz, a 5V 486SX µP running at full speed uses 685 mA of current. This figure includes a margin for high supply voltage, low operating temperature, and test guard band. Typical µP operation requires 15% less current than specified (590 mA). Only a small portion of the CPU circuitry draws less power when a wait state occurs on the µP's external bus. When the bus-execution unit idles during a wait state, the 486SX µP's five-stage internal pipeline (instruction fetch, two decode stages, execution, and register write-back) is still active. We calculate a 15% reduction in energy consumption during wait states because no more than two or three wait states occurs per bus cycle. The power reduction can be greater for a design that invokes more wait states.

The mix of bus-cycle operations varies widely with software applications and OSs. Determine a reasonable, nominal bus-cycle mix to evaluate hardware performance for your application. In our spreadsheet analysis (**Table 2**), we compare the bus-cycle mix and Level 1 cache-miss rates for each hardware alternative to determine µP performance and energy use. We determine sensitivity to the bus-cycle mix and the selected average miss rate by evaluating the alternatives and increasing and decreasing the miss-rate value. Similarly, you can evaluate sensitivity to the average bus mix by altering the ratio between reads and writes.

We evaluated performance for each alternative by calculating the number of elapsed clock cycles to execute 1 billion operations. An operation is an instruction fetch/execution cycle or a data read/write cycle. Given the bus-cycle mix, we select memory speeds and then determine the number of wait states for each bus-access type. Although wait states reduce the power consumption per cycle, they add to a task's overall execution time.

Ideally, a system should execute the selected operations in 1 billion clock cycles. The memory architecture imposes wait states that cause the number of clock cycles to complete the

PORTABLE PC DESIGN

task to exceed 1 billion cycles.

It is difficult to determine power consumption in CMOS circuits because transistors use energy when they are toggled and leak energy when they are not toggled. Consequently, we use many analysis methods to calculate the instantaneous peak power of the components and use this figure to evaluate energy use. This method can be misleading because a component that consumes more peak power can use less energy overall. Although power dissipa-tion is the rate of energy use, power consumption is *power×time*. A good analysis evaluates standby power multiplied by the standby time in addition to active power multiplied by the active time.

Also, a peak-power calculation alone does not account for I/O energy use. Although manufacturers specify operating current with no loading on devices' outputs, ICs in the real world drive capacitive loads, and it takes energy to alter the voltage of the load capacitance. Take the load energy (calculated as $\frac{1}{2}CV^2$ into account in analyzing power consumption.

The four types of DRAM refresh that can affect a system's power consumption are: standard, extended, self-refresh, and pseudostatic. Manufacturers screen DRAMs to find chips that can hold data for long times between refresh cycles. These "extended-refresh" devices use less standby power. Our analysis uses the conventional, standard-refresh DRAM and extended-refresh devices. Self-refresh DRAMs do not need an external clock to continue refreshing the device so the DRAM controller can cease operation when the system is idle, reducing power dissipation. Pseudostatic RAMs are similar to the self-refresh devices, except the pseudostatic devices' address rows and columns are not multiplexed. Both the self-refresh and pseudostatic DRAMs are not yet widely available, and pseudostatic RAMs have not successfully penetrated the PC market. Therefore, we omit these products in our study.

In a simple design, a secondary cache subsystem adds approximately 2000 to 4000 gate equivalents to a chip set. A DRAM controller uses 1000 to 2000 gates. These gates consume energy at the rate of 6 µW/MHz/gate in a 5V gate array and 4 µW/MHz/gate in a 3.3V gate array. When a system is in standby mode, gates do not truly operate at zero power. You observe zero-power operation only if you stop the clock to the gate. Therefore, our analysis includes power consumption values of 0.3 µW/5V gate and 0.2 µW/3.3V gate in standby mode.

One difficulty of a performance and power analysis is determining how many gates run at which frequencies. If the chip-set vendor cannot supply accurate data, you can assume power dissipation based on the device's data-sheet maximum currents for each operating mode. If you use such an assumption, you can test sensitivity by adjusting the numbers up and down in the spreadsheet model to establish the affected range.

Table 1 shows the power-dissipation data in our analysis. The DRAM controller's clock-stopped numbers assume some dynamic operation when the CPU goes idle to account for DRAM-refresh requirements. The power data does not include additional components in chip sets such as I/O control.

TABLE 1—POWER DISSIPATION FOR SYSTEM COMPONENTS

Device	Supply voltage (V)	Active power (mW)	Standby power (mW)	Power dissipation (Clock stopped, mW)
DRAM controller	5	60	30	10
DRAM controller	3.3	40	20	5
Cache controller	5	200	60	0.6
Cache controller	3.3	135	40	0.4

Analysis results

Table 2 lists the results of the 21 design options we consider in our analysis. Case 1 is the reference or base case. The **table** divides the cases into seven major groups. The first group (cases 1 through 6) employs variations based around a 5V CPU and 5V DRAM. The second group (cases 7 and 8) also uses 5V DRAM but substitutes a 3.3V CPU. The third group (cases 9, 10, and 11) employs both a 3.3V CPU and 3.3V DRAM.

The fourth group (cases 12 through 14), employs a 5V CPU and DRAM, but we threw high cache miss rates into the simulation to test for sensitivity. The fifth group (cases 15 through 17) also looks for that sensitivity, using a 3.3V CPU and 3.3V DRAM. The sixth and seventh groups (cases 18 and 19 and 20 and 21, respectively) examine the effect of using extended-refresh DRAM in both 5 and 3.3V systems.

The last two columns of **Table 2** show figure-of-merit improvements (if any) over the baseline case (Case 1). The next-to-last column in **Table 2** shows improvement over Case 1 for the first case of each of the seven groups. The last column in the **table** shows additional incremental improvements achieved by modifying the configuration of the first case in that group.

In each case, we execute an application consisting of 1 billion clock cycles followed by a 5-minute idle period. This scenario assumes a 90% idle time for mobile-computer operation. A more realistic idle time is 70 to 85%. We use the more conservative model because the addition of components increases standby power needs. If the addition of Level 2 (secondary) cache shows benefits in worst-case scenarios, then we can project its efficiency in less extreme conditions.

For all cases, except where indicated, we halted the clock after 60 sec of idle time to emulate some power management. The final 4 minutes of operation were in the lowest energy consumption mode (rather than off). The figure of merit that compares the options is

$1\times10_9$ operations/(CPU and memory subsystem energy * execution time).

Larger figures of merit indicate better performance using less power. Cases with SRAM secondary cache, one additional 32k×8-bit SRAM, include a tag RAM in the energy calculation at the same voltage as the cache SRAM. For example, in Case 6, the energy figures include one additional 3.3V, 32k×8-bit SRAM acting as a tag RAM. This is nec-

essary because **Table 1** doesn't account for the tag.

Table 2 clearly shows the importance of stopping the clock. You incur a 24% energy penalty if the clock runs continuously rather than stopping after 60 sec of idle time. All components use more energy when the clock is running. Restarting the CPU and core devices requires less time and energy than spinning a hard disk drive up to speed.

The **table** shows a 9.6% improvement in the figure of merit when you add a 5V secondary cache (four, 32k×8-bit SRAMs for cache data, and one 32k×8-bit SRAM for cache tag) to a 5V system. Although the power consumption is higher in standby mode, active energy consumption is considerably lower. In this case, the performance improvement outweighs the overall energy increase. In comparing cases 4 and 2 (with clock running), an overall decrease in the figure of merit appears when you add cache (Case 4). This further emphasizes the need to control the system clock.

In cases 5 and 6, the secondary cache employs 3.3V devices. Case 5 uses four 32k×8-bit SRAMs for the data cache, and Case 6 uses a 32k×32-bit synchronous-burst SRAM. Both cache configurations employ 5V-tolerant parts. These ICs run on a 3.3V supply, but they don't require buffering to interface directly with the 5V CPU. These two cases show

TABLE 2—SPREADSHEET RESULT OF POWER SIMULATIONS

Case No.	Option	Elapsed times	Active-period energy (J)	Standby-period energy, excluding CPU (J)	Standby period energy (J)	T= total time
1	5V DRAM	38.388	205.6	18.822	303.8	338.388
2	5V DRAM, clock always running	38.388	205.6	24.882	467.4	338.388
3	5V CPU, 5V DRAM, four 5V 32k×8-bit cache RAMs	31.421	142	47.466	332.5	331.421
4	5V CPU, 5V DRAM, four 5V 32k×8-bit cache RAMs, clock always running	31.421	142	147.82	590.3	331.421
5	5V CPU, 5V DRAM, four 3.3V 32k×8-bit cache RAMs	31.421	126.9	31.476	316.5	331.421
6	5V CPU, 5V DRAM, one 3.3V 32k×32-bit cache RAM	31.421	124.9	30.288	315.3	331.421
7	3.3V CPU, 5V DRAM	38.388	143.9	18.822	137	338.388
8	3.3V CPU, 5V DRAM, 3.3V 32k×32-bit cache RAM, 3.3V cache controller	31.421	71.7	29.04	147.2	331.421
9	3.3V CPU, 3.3V DRAM	38.388	89.2	7.6789	125.9	338.388
10	3.3V CPU, 3.3V DRAM, 3.3V 32k×32-bit cache RAM	31.421	61.1	17.897	136.1	331.421
11	3.3V CPU, 3.3V DRAM, four 32k×8-bit cache RAMs	31.421	62.9	19.085	137.3	331.421
12	5V CPU, 5V DRAM, high miss rates	46.776	263.5	18.822	303.8	346.776
13	5V CPU, 5V DRAM, high miss rates, four 3.3V 32k×8-bit cache RAMs	32.842	157.2	31.476	316.5	332.842
14	5V CPU, 5V DRAM, high miss rates, 3.3V 32k×32-bit cache RAM	32.842	154.2	30.288	315.3	332.842
15	3.3V CPU, 3.3V DRAM, high miss rates	46.776	114.3	7.6789	125.9	346.776
16	3.3V CPU, 3.3V DRAM, high miss rates, four 3.3V 32k×8-bit cache RAMs	32.842	78.5	19.085	137.3	332.842
17	3.3V CPU, 3.3V DRAM, high miss rates, 3.3V 32k×32-bit cache RAM	32.842	75.8	17.897	136.1	332.842
18	5V CPU, 5V extended-refresh DRAM	38.388	204.6	5.6762	290.7	338.388
19	5V CPU, 5V extended-refresh DRAM, 32k×32-bit cache RAM	31.421	123.6	17.142	302.1	331.421
20	3.3V CPU, 3.3V extended-refresh DRAM	38.388	88.8	2.6712	120.9	338.388
21	3.3V CPU, 3.3V extended-refresh DRAM, 32k×32-bit cache RAM	31.421	60.9	15.544	133.7	331.421

considerably improved figures of merit. This analysis presumes the availability of a 3.3V tap from the switch-mode power supply so no additional energy is allocated to convert 5 to 3.3V. If a 3.3V power-supply tap is not available, take the additional power requirements of a linear regulator into account.

During operation and in standby mode, the single 32k×32-bit SRAM-based secondary cache uses slightly less energy than the cache built from four 32k×8-bit SRAMs. One additional consideration in this case is the circuit-board design. The single 32k×32-bit SRAM in a TQFP uses 0.55 in.^{2} of board space, and the four 32k×8-bit devices, packaged in SOJ packages, use 1.1 in^2. This reduction in real-estate consumption can make a significant difference to a crowded circuit board, especially in mobile computers.

Cases 7 and 8 reflect some of today's harsh market realities. Low-voltage CPUs really need the more energy-efficient 3.3V DRAMs, but these memories are still in short supply. Thus, cases 7 and 8 reflect the results of using a 3.3V CPU with 5V DRAM. Case 7 (3.3V CPU without a secondary cache) shows an improvement of 81% over the 5V CPU design. Adding a 3.3V secondary cache further improves this design by 31%.

In cases 9 through 11, the cache, CPU, controllers, and DRAM all run on 3.3V. Thus, as 3.3V DRAMs become more available and less costly, all-3.3V systems should dominate system designs.

Cases 12 through 17 illustrate sensitivity analysis. When you make a set of assumptions, check your conclusions' sensitivity to those assumptions. We developed a set of miss rates for levels 1 and 2 caches and applied these rates against the original bus-cycle mix (which comprises 11% internal cycles, 52% instruction-read cycles, 21% data-read cycles, and 16% data-write cycles). Each of the three internal bus-cycle operations (Level 1 cache operations) uses different miss rates.

When you add Level 2 cache, the 128-kbyte direct-mapped cache uses a set of miss rates that conforms to an average rate that falls between DOS' and Windows' typical miss rates. Windows is more sensitive to miss rates than is DOS. To determine the power-consumption sensitivity to miss rates, cases 12 through 17 use miss rates in levels 1 and 2 caches that are twice as high as those of the other cases. This doubling more closely resembles a true Windows operating environment. Level 2 caches improve the computed figures of merit by 16% to 26%, depending on CPU and DRAM voltage selections.

The last group of options in **Table 2** explores an effort to reduce DRAM energy in the cacheless cases through the use of extended-refresh DRAMs. Extended-refresh DRAMs have lower standby energy demands because they need refreshing much less often than regular DRAMs. If any of the cases casts doubt upon the usefulness of Level 2 cache, it would be these because we figure a high standby time into the analysis. But even in this scenario, adding the secondary cache improves the figures of merit from 10 to 19%.

The 33-MHz, 486-μP-based portable computer hardly represents a performance pinnacle. Clock-doubling and -

E= total energy (J)	**Figure of merit** (1E9/(E*T))	**Improvement over baseline case** (%)	**Incremental improvement** (%)
509.4	5801	Baseline	
673	4391		–24.303
474.5	6359		9.622
732.3	4120		–28.975
443.3	6806		17.327
440.1	6855		18.177
280.9	10521	81.362	
218.9	13780		30.983
215.1	13738	136.827	
197.2	15302	11.38	
200.1	15075	9.733	
567.3	5083	–12.38	
473.7	6343		24.794
469.5	6399		25.891
240.2	12005	–12.613	
215.7	13927		16.001
211.9	14179		18.104
495.3	5966	2.850	
425.7	7088		18.802
209.7	14093	2.582	
194.6	15504		10.010

tripling µPs are finding their way into the portable-computing market. However, a µP consumes energy when executing instructions and when waiting. During wait states, the µP performs no useful work, but it consumes 80 to 85% of the energy it normally uses during full operation. Each bus wait state in a clock-tripled system corresponds to three internal wait states in the CPU. Although the µP performs no work, it still needs 80% of the active energy for each of these three wait-state cycles. Unless you add secondary cache to the number of wait states, the clock tripling reduces the system's overall energy efficiency. Therefore, adding Level 2 cache improves the efficiency of clock-doubled and -tripled systems even more than it does in unity-clock systems.

Core mobile-computer systems will soon include Level 2 cache because of the performance advantages it brings. IC vendors will most likely integrate tag SRAM into chip sets to save board space. Although tag RAMs integrated into ASICs have lower performance than external specialty tag SRAMs, portable computers usually do not need to perform at workstation levels, so you can achieve zero-wait-state results with ASIC-based tag RAMs. Thus, a single 3.3V 32k×32-bit SRAM would be the most likely choice for the Level 2 cache RAM because it requires the least amount of circuit-board space. EDN

Author's biography

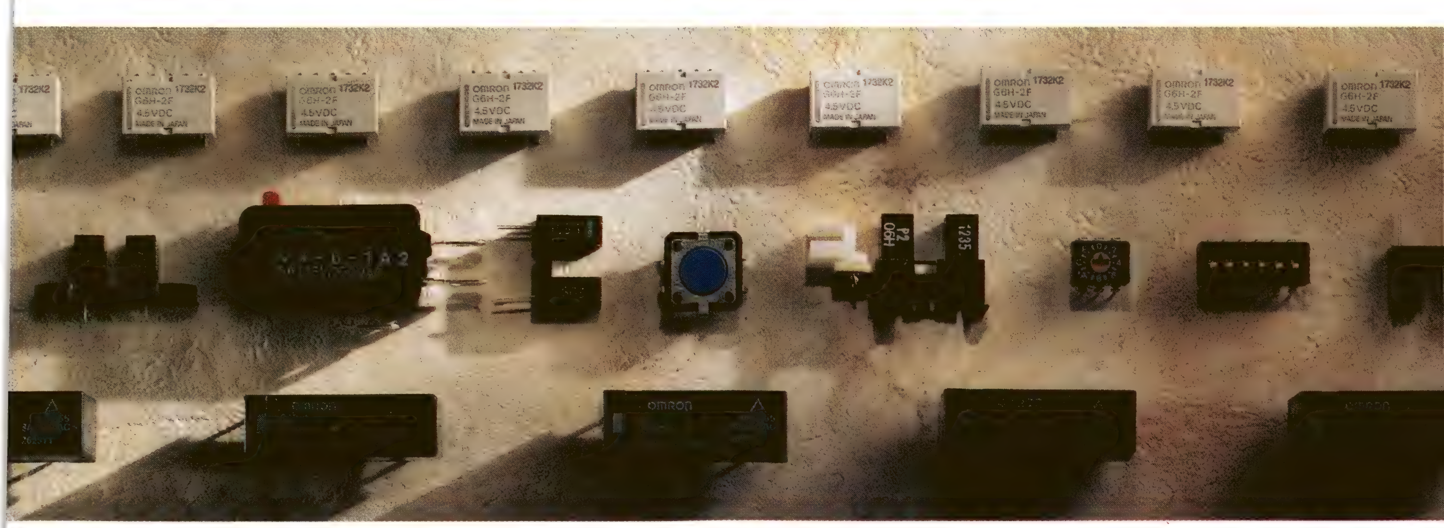
J Thomas Pawlowski is strategic SRAM applications engineer at Micron Semiconductor Inc in Boise, ID. He has worked at Micron for 2½ years. In his current position, he architects new products and assists customers and engineers with design activities. Pawlowski has also helped develop SyncBurst SRAM, PCs, and aerospace embedded-control systems. He received a BSEE from the University of Waterloo, Waterloo, ON, Canada. In his spare time, Pawlowski enjoys scuba diving, high-performance car design, music, and studying the philosophy of religion.

VOTE

Please use the Information Retrieval Service card to rate this article (circle one):

High Interest	Medium Interest	Low Interest
595	596	597

f You Think Omron Only Makes Relays, Read Between Our Lines.



It's true we're the world's number one relay supplier. So it's not surprising to learn that design engineers and specifiers know us for our relays.

But we also manufacture the world's most complete line of switches and photomicrosensors.

For years we've been building all types of switches, photomicrosensors, and relays for leading companies that manufacture telecommunications products, home and office electronics, computer peripherals, appliances, and HVAC equipment, just to name a few.

Proven reliability makes Omron relays, switches, and photomicrosensors the preferred choice of design engineers and specifiers worldwide.

What does all this mean? That's simple. Our expertise has led to the development of standard components for all kinds of applications. And when you can fit a standard switch to your custom application, you're looking at a considerable cost savings. Plus you'll see your design go into production that much faster.

In switches alone, we have basic switches, mechanical keyswitches, rotary and in-line DIP, thumbwheel and rocker switches, amplified and non-amplified photomicrosensors, PCB mount and connector-ready photomicrosensors, as well as lighted and oil-tight pushbuttons.

And everything Omron makes is 100% tested, available to you worldwide, and backed up by outstanding technical and distribution support.

We've even set up a fax system called *ControlFax* that sends you technical data sheets through your fax machine when you dial 1-708-843-1963.

To find out if Omron has the component solution you're looking for, call now to receive our Standard Products Catalog. If you're someone who responds to innovation and more efficient ways of doing business, it's a story worth reading.

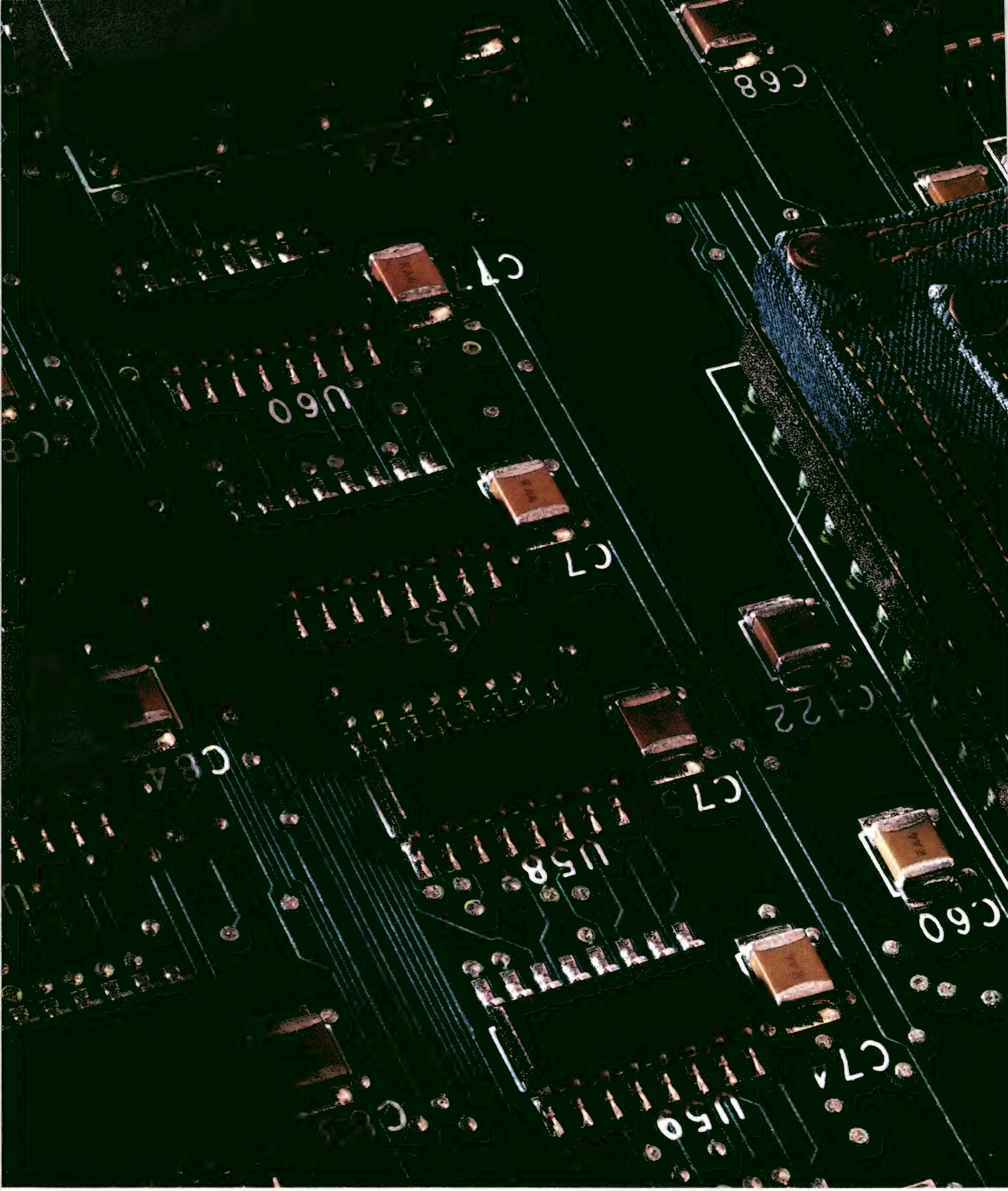
1-800-55-OMRON

ASK FOR OUR STANDARD PRODUCTS CATALOG. IT'S FREE!

OMRON®

WE HAVE THE FUTURE IN CONTROL

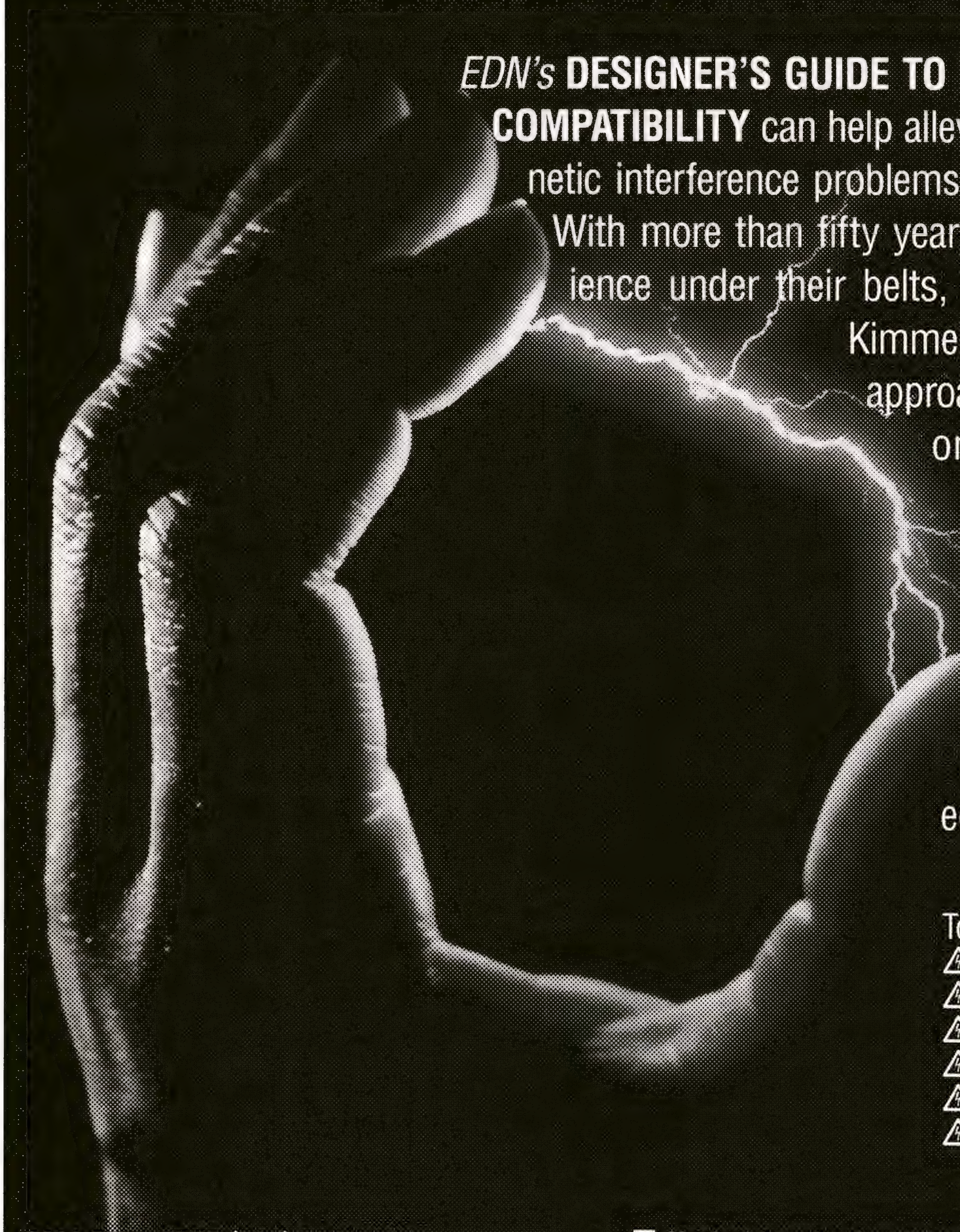
CIRCLE NO. 159



Choose an embedded processor

i960
intel

ELECTROMAGNETIC COMPATIBILITY



EDN's **DESIGNER'S GUIDE TO ELECTROMAGNETIC COMPATIBILITY** can help alleviate any electromagnetic interference problems you may encounter. With more than fifty years of collective experience under their belts, Daryl Gerke and Bill Kimmel take a nontraditional approach to EMI, focusing on practical insights and ideas about EMI to help you identify, prevent, and solve your EMI problems as you design your equipment. 82 pages

Topics include:

- ⚠ noise and interference
- ⚠ EMI regulations
- ⚠ power disturbances
- ⚠ circuit boards
- ⚠ grounding
- ⚠ troubleshooting

CALL TOLL FREE (800) 523-9654
(FAX 708-390-2779) to order.
Or fill out this coupon and mail it to:

Cahners Reprint Services
1350 E. Touhy, Des Plaines, IL 60018

Please send me ____ copies of EDN's DESIGNER'S GUIDE TO ELECTROMAGNETIC COMPATIBILITY@ 19.95. ____

Sales tax (orders shipped to these states must include applicable sales tax : CA, CT, MA, NJ, NY) ____

Shipping: $3.50/copy (US), $15.00/copy (foreign)
$3.00/additional copy ____

Total ____

☐ My check is enclosed payable to Cahners Reprint Services

Charge my credit card: ☐ Master Card ☐ Visa ☐ Amex

CREDIT CARD # EXPIRATION DATE SIGNATURE

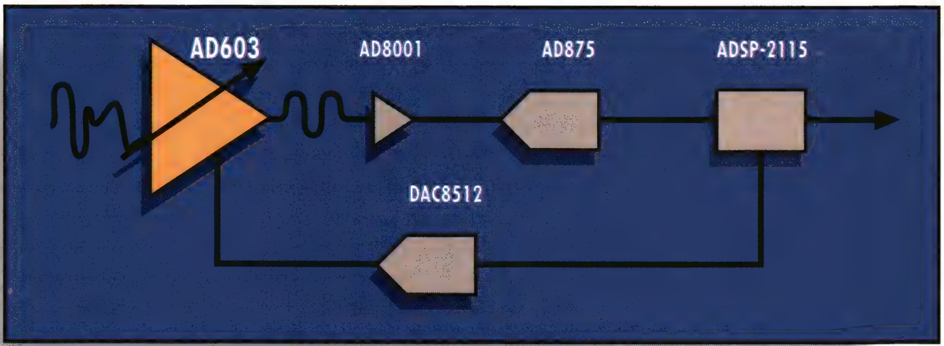
NAME

COMPANY

ADDRESS

CITY STATE ZIP PHONE

New Class Of Variable Gain Amplifiers Offer Wideband Gain Control.



Analog Devices has taken every criteria for variable gain amplifiers and made them a generation better. Greater gain accuracy. Less noise. Linear-in-dB control. Lower solution cost. The high integration of our variable gain amplifiers provides a complete, easy to use solution: simply connect the power, input and gain control voltage and you're in control.

SPECIFICATION	AD600	AD602	AD603
Channels	Dual	Dual	Single
Gain Range*	0 dB to +40 dB or 0 dB to +80 dB cascaded	-10 dB to +30 dB or -20 dB to +60 dB cascaded	-10 dB to +30 dB through +10 dB to +50 dB
Input Noise Spectral Density	1.4 nV/√Hz	1.4 nV/√Hz	1.3 nV/√Hz
Signal Gain Accuracy (typ)	±0.25 dB	± 0.25 dB	±0.4 dB
Bandwidth (MHz)	35	35	90
Price/amp**	6.00	6.00	3.95

LOWER NOISE, HIGHER PERFORMANCE, BETTER VALUE THAN ALL OTHER VOLTAGE CONTROL AMPLIFIERS

AD600, AD602. For applications that demand high accuracy and integration, our dual channel AD600 and AD602 variable gain amplifiers provide an optimum solution. They're ideally suited for demanding medical ultrasound, non-destructive ultrasonic testing, and RF applications.

AD603. Our new variable gain amplifier is a high speed, low cost solution, with solid performance. The AD603 features a single channel, programmable 40 dB gain range that's ideal for cost and performance driven applications such as video, instrumentation, sonar, RF and IF AGC applications.

For a data sheet and more information on AD603 samples and evaluation board, call Analog Devices toll free today, at 1-800-ANALOGD (262-5643)†. Or fax your request to 617-821-4273.

SPECIAL EVALUATION BOARD OFFER!
Call 1-800-ANALOGD (262-5643)

ANALOG DEVICES

Analog. Digital. Solutions.

Analog Devices, Inc., One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106.
Distribution, offices and application support available worldwide.

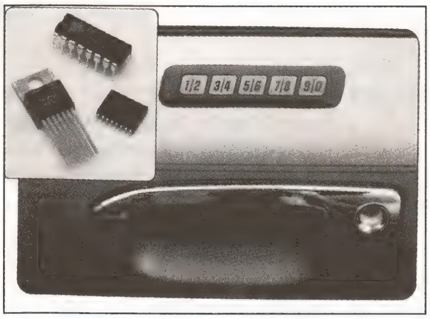
* AD603 is gain range pin programmable
** USD 1000s, recommended resale, FOB USA.

† Outside U.S., please call 617-461-3392.

CIRCLE NO. 111

FREE INFO, FREE POSTAGE
Use our postage-paid reader-service cards to get more information on any of these products.

RAMDAC provides 64-bit video interface. The TVP3025 RAMDAC provides a complete back-end graphic system by interfacing a graphic controller device directly to VRAM. The device operates at speeds of 135, 175, or 220, providing 24-bit true color at 1024×768 resolution and 16-bit color at up to 1600×1280 resolution. The TVP3025-135PCE costs $23.75 (1000). **Texas Instruments Inc**, Denver, CO. (800) 477-8924 ext 4500. **Circle No. 382**



Multifunction linear-voltage regulator extends battery life. The CS-8151 linear-regulator IC provides a single 5V regulated output with a 100-mA current capability to power a microprocessor. A single external capacitor sets the reset-pulse width, wake-up frequency, and reset-to-wake-up delay time. A wake-up pulse train periodically activates a μP to check for service requests. If the μP does not respond to the wake-up pulse, the device issues a reset signal. $1.56 (10,000). **Cherry Semiconductor Corp**, East Greenwich, RI. (401) 885-3600. **Circle No. 383**

Embedded-system controller works with IDT's R3051 32-bit RISC CPU. The GT-32011 provides a tightly coupled CPU interface; a DMA interface for an external coprocessor; a ROM controller for up to 20 Mbytes; a high-performance DRAM controller for up to 40 Mbytes; a fully compliant IEEE 1284 bidirectional Centronics interface; three high-performance DMA channels, a 16-bit I/O bus, an I/O controller with various DMA, packing, and unpacking features; a 24-bit timer/counter; and other functions. $17.95 (10,000). **Galileo Technology Inc**, San Jose, CA. (408) 451-1400. **Circle No. 384**

Single-chip SCSI designed for fast and low-cost SCSI-2 PCI adapter boards. According to the company, the $19.95 (1000) AM53C974A allows companies to quickly develop SCSI adapters at low cost. In addition to the chip, the company provides complete licensable SCSI software, an FCC-tested reference platform, and complete design support. The chip contains a fast SCSI-2 core, bus-master DMA engine, and PCI-Bus interface unit. Automatic SCSI device assignment provides Plug-and-Play compatibility, sampling now. **Advanced Micro Devices Inc**, Sunnyvale, CA. (408) 732-2400. **Circle No. 385**

16-bit delta-sigma ADC converts 192 ksamples/sec. The ADC16471 $11.50 (1000) with internal-voltage reference and the 16071 $11.10 (1000) requiring an external-voltage reference have adjustable throughput rates of 7 to 192 ksamples/sec. The converters include a fourth-order modulator, provide 64 times oversampling, and include a linear-phase digital antialiasing filter. The device dissipates 500 mW at the maximum sample rate and has a 6.5 mW power-down mode. **National Semiconductor Corp**, Santa Clara, CA. (800) 272-9959. **Circle No. 386**

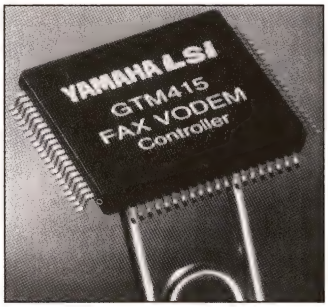
Variable gain-control circuit on single IC. The EL4451C variable-gain amplifier has a 70-MHz bandwidth, a gain of two, and attenuation greater than 70 dB at 4 MHz. The bipolar IC operates on power supplies from ±5 to ±15V and has an analog-input range of ±2V. The IC is designed for variable filters, level controls, and automatic gain controls. Available in 14-pin P-DIP and 14-lead SO packages,from $3.33 (1000). **Elantec Inc**, Milpitas, CA. (408) 945-1323. **Circle No. 387**

Positive-to-negative dc-to-dc converter has 1.5 to 15V range. The TC7662B converter has an operating current of 80 μA and requires two external capacitors. The device can also be connected to function as a voltage doubler, multiplier, or divider. Available in an 8-pin DIP or SOIC package. $0.88 (1000). **Telcom Semiconductor Inc**, Mountain View, CA. (415) 968-9241. **Circle No. 388**

Complete current-sensing IC includes sense resistor in 8-pin SO package. The MAX471 uses an inter-

nal 35-mΩ resistor that measures battery currents up to ±3A with accuracy to 2%. The IC operates from 3 to 6V and draws less than 100 μA. The MAX472 uses an external resistor for applications requiring higher current or greater precision at low current levels. From $1.90 (1000). **Maxim Integrated Products**, Sunnyvale, CA. (408) 737-7600 ext6087.
Circle No. 389

20-bit delta-sigma ADC has 110-dB dynamic range. The CS5390 generates a 20-bit value for two channels in serial form and samples at up to 50 kHz per channel. The converter uses a 64-times oversampled, fifth-order modulator to achieve its wide dynamic range. An on-chip digital antialiasing filter reduces external filter requirements to a single external RC filter per channel. The CS5390 is packaged in a 28-pin DIP and costs $58 (1000). **Crystal Semiconductor Corp**, Austin, TX. (512) 422-7555.
Circle No. 390



Fax vodem controller operates on 3.3V. The GTM415 replaces the GTM407 with new features and the ability to operate from 3.3, 5, or mixed-voltage systems. The new device offers higher speed and an improved baud-rate generator and controls the fax, voice, data, and caller-identification functions. Packaged in an 80-pin QFP or TQFP, the IC costs $11 (1000). **Yamaha Systems Technology Division**, San Jose, CA. (408) 437-3133.
Circle No. 391

Dc-to-dc converter minimizes RF interference in portable communication products. The TK65015 provides a 3V regulated output at up to 15 mA from input voltages as low as 0.9V. The IC issues a reset signal if the output falls below 2.4V. Low switching transients and a laser-trimmed internal oscillator minimize interference for communication systems using a 455-kHz IF. $1.40 (1000). **Toko America Inc**, Mt Prospect, IL. (708) 297-0070. **Circle No. 392**

Two-chip set for PCMCIA flash-memory cards. The CL-ST1000 PCMCIA/ATA flash-memory controller and CL-ST2000 space manager simplify the creation of flash memory-based storage systems that emulate rotating magnetic hard disk drives. The chips are available with a storage-card-reference design to reduce the time and cost of developing flash-memory cards. You can create a 2-Mbyte flash-storage card using the CL-ST1000, an 8-bit μP, and a flash-memory chip. Creating larger flash-storage cards also requires the use of the CLS-ST2000 space manager. Samples of both chips will be available in the fourth quarter. $22 (1000). **Cirrus Logic Inc**, Fremont, CA. (510) 226-2147. **Circle No. 393**

Fast-charge IC for NiMH and NiCd batteries features peak-voltage detection. The bq2002 has peak-voltage detection for fast-charge termination of NiMH batteries. The charger

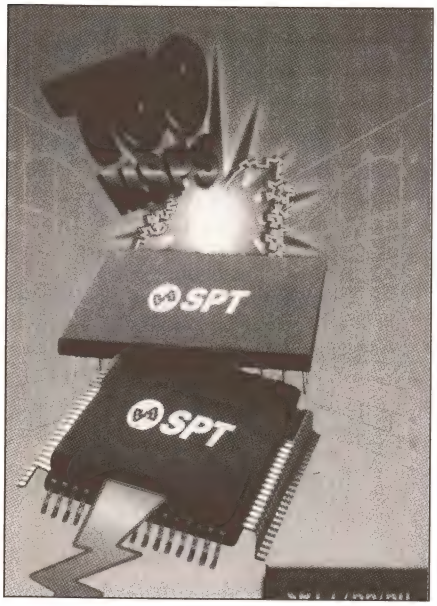
also terminates charge based on negative-delta voltage detection for NiCd batteries. Fail-safe terminations include maximum temperature and maximum charge time. Other features include a charge-inhibit pin to temporarily disable fast charge, a low-power standby mode, battery-temperature and voltage qualification before fast charge, and pulse trickle and top-off charge control. \$1.45 (5000). Development systems are \$75. **Benchmarq Microelectronics Inc**, Carrollton, TX. (214) 407-0011.

Circle No. 394

Converter for battery-operated systems has low-battery detector and up to 88% efficiency. The LT1303 dc/dc converter is available in a fixed 5V, 200-mA version and an adjustable-output version that delivers up to 25V. The converter operates on 1.8 to 5V, with typical conversion efficiencies ranging from 80 to 88%, depending on the input voltage and load current. An integral low-battery detector provides an open-collector output that goes low when the input voltage drops below a level set by a resistor divider. Quiescent current is 120 μA, and a shutdown pin reduces the current to 10 μA. The IC requires external surface-mount inductors and capacitors. \$2.42 (1000). **Linear Technology Corp**, Milpitas, CA. (408) 432-1900.

Circle No. 395

8-bit ADC samples at up to 750 Msamples/sec. The SPT7750/55 flash converters have a proprietary input preamplifier that reduces input capacitance to 15 pF. A proprietary gray-code output-decoding scheme limits metastable errors to less than 1 LSB. For a 50-MHz analog input, the typical S/N ratio is 47 dB, and the typical THD is 46 dB. To simplify capturing the output data, the converters have two independent, demultiplexed output-data banks, reducing the data rate to one-half the conversion rate. The input voltage range is –2 to 0V. Operating from a –5.2V supply, the converters dissipate 5.5W and use ECL-compatible levels. The SPT7750 costs \$295 (100), and the SPT7755 costs \$495 (100). **Signal Processing Technologies Inc**, Colorado Springs, CO. (719) 528-2300.

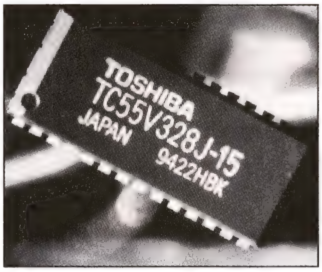


Circle No. 396

Power-interface switch for PCMCIA cards integrates all discrete transistors. The TPS2201IDF independently switches the power supplied to one or two cards among 3, 5, and 12V. The switch uses an internal charge pump to create the higher voltages to

drive switches, allowing the system to shut down the 12V supply, except when required for writing or erasing EEPROM. The switch IC also has current- and thermal-protection circuitry, eliminating the need for external protection circuits. $6.67 (1000). **Texas Instruments Inc**, Denver, CO. (800) 477-8924 X4500.
Circle No. 397

3.3V, 256-kbit RAM has 15-nsec access. The TC55V328P/J 32k×8-bit RAM is available with access times of 15, 20, and 25 nsec. Operating current is 100 mA for the 15-nsec versions, dropping to 80 mA for the 25-nsec version. Two standby modes draw 20 mA I_{DDS1} and 300 μA I_{DDS2}. The memory chips are available in 28-pin DIP or SOJ packages. Sample prices are $5.50 for the 15-nsec version to $4.50 for the 25-nsec version. **Toshiba America Electronic Components Inc**, Irvine, CA. (800) 879-4963.
Circle No. 398



12-bit, 600-ksample/sec ADC offers low power and low cost. The AD7892 consumes 60 mW from a 5V supply and costs $12.75 (1000). A sleep mode further reduces power consumption to 1.25 mW. The converter includes a track-and-hold amplifier, a voltage reference, control logic, and parallel and serial interfaces for connection to μPs, μCs, and DSPs. Three input-voltage ranges are available: ±5 or ±10V, 0 to 2.5V, and ±2.5V. The device comes in 24-pin DIP and SOIC packages. **Analog Devices Inc**, Wilmington, MA. (617) 937-1428.
Circle No. 399

256k×8-bit, burst-mode DRAM challenges VRAM. The V53C8257H DRAM has a 15-nsec burst cycle for pixel data, plus a 20-nsec hyperpage and extended-data-out cycle time. Although the burst-mode DRAM permits a slightly higher data rate than the fastest VRAM, 64-bit graphics accelerator designs can still gain a 10 to 20% benchmark performance advantage for VRAMs by taking advantage of their dual ports. The cost for VRAM is, however, significantly higher than for this DRAM. $9 (1000). **Mosel Vitelic**, San Jose, CA. (408) 433-6000.
Circle No. 400

Power-factor-correction preregulator IC uses zero voltage transition. The UC3855A/B accommodates switching frequencies up to 500 kHz with the addition of a small MOSFET, a diode, and an inductor. The device's active snubbing feature makes it effective in boost power-factor-correction applications. The IC turns off the main diode at a controlled rate and activates the main switch with 0V across it, allowing the device to work at high frequencies and use smaller magnetics. The device also features fixed-frequency and average current-mode control. $4.45 (1000). **Unitrode Integrated Circuits Corp**, Merrimack, NH. (603) 424-2410.
Circle No. 401

Single-chip decoder for MPEG-2 compressed data. The MPEG-2 decoder suits full-motion digital

CIRCLE NO. 92

PERFORMANCE ARTIST

Ricoh transforms color copying into an art form. Introducing the world's most efficiently designed digital color copier – the RICOH NC5006. Its palette of capabilities will astound you. Like the world's fastest first copy – 15 seconds. The world's smallest toner particles – for the highest quality color copies. And the world's first Display Editor – for unmatched editing creativity. The NC5006 is truly a masterpiece of technology.

For a private showing, call 1-800-63-RICOH and we'll send you a free video.

Free Video

THE NAME TO KNOW

RICOH®

1-800-63-RICOH

Official Copier and Fax

USA Volleyball Team

CIRCLE NO. 77

PICO POWER

- Dual Isolated Outputs (standard)
- Up to 100 VDC Output (standard)
- Fixed Frequency • Parallel Operation
- Wide Input Ranges 18-380 VDC
- Regulated Outputs
- Continuous Short Circuit Protection
- Low Cost

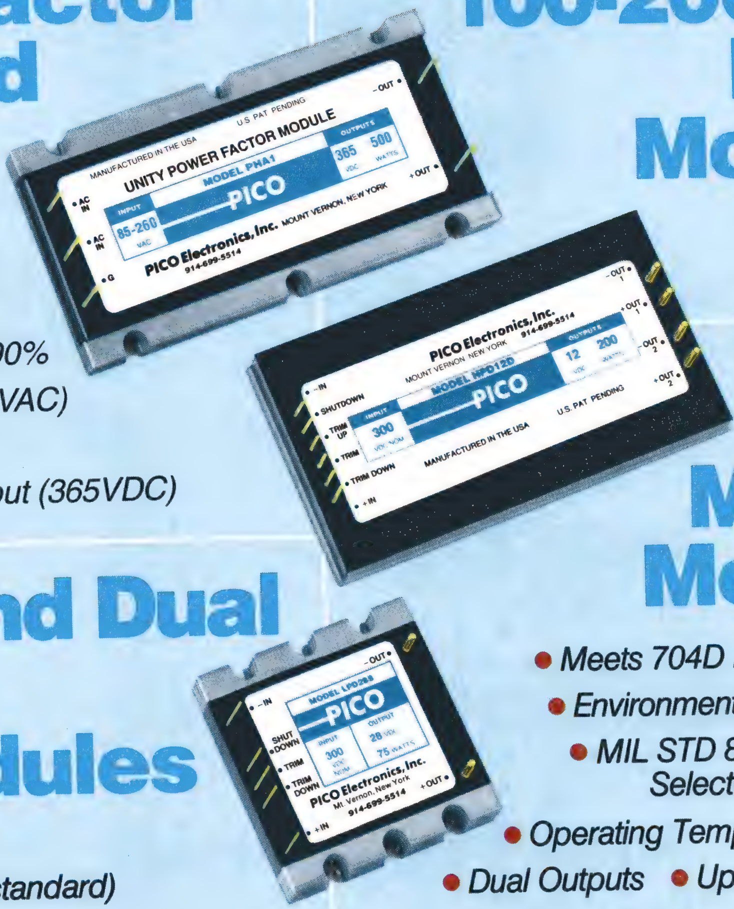
Single and Dual 100-200 Watt Power Modules

Unity Power Factor Front End

for AC to DC applications

HARMONIC ATTENUATOR

- *Power Factor .99*
- *Efficiency greater than 90%*
- *Universal Input (85-260VAC)*
- *Up to 500 Watts*
- *Regulated Voltage Output (365VDC)*



Military Modules

- Meets 704D Input Specifications
- Environmental Testing Available
- MIL STD 883 • MIL STD 810 Selected Screening
- Operating Temp. −55°C to +85°C
- Dual Outputs • Up to 100 VDC Output
- Hi-Temp Full Power Burn-In Available
- Special Output Voltages Available

Single and Dual 75 Watt Mini Modules

- Miniature Size
- Dual Isolated Outputs (standard)
- Up to 100 VDC Output (standard)
- Fixed Frequency/Parallel Operation
- Wide Input Ranges 18-380 VDC
- Continuous Short Circuit Protection
- Regulated Outputs • Low Cost

Send for FREE PICO Catalog

PICO Electronics, Inc.

453 N. MacQuesten Pkwy., Mt. Vernon, N.Y. 10552

Call Toll Free 800-431-1064

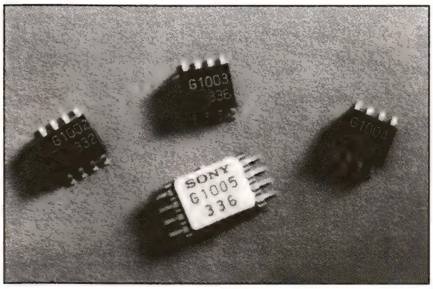
in New York Phone 914-699-5514

FAX 914-699-5565

CIRCLE NO. 164

video applications. The IC decompresses MPEG-1 or -2 digital video information in compliance with the ISO standard for MPEG-2, Main Profile at Main Level, and CCIR601 resolution. The 3.3V device draws 1W and comes in a 208-pin QFP. $98 (1000). **IBM Microelectronics**, Fishkill, NY. (800) 426-0181, ext 1501. **Circle No. 402**

Low-power 10-bit DAC has voltage output. The MAX503/504/515 voltage-output DACs have an output settling time of 25 μsec. The parallel-input MAX503 has an internal voltage reference and draws 250 μA from a +5 or ±5V supply. The serial-input MAX504 also has an internal voltage reference and draws 260 μA from a 5V supply. The serial-input MAX515 works with an external reference and draws 140 μA from a 5V supply. The DACs are pin- and software-compatible with the company's 12-bit voltage DACs. From $2.50 (1000). **Maxim Integrated Products**, Sunnyvale, CA. (408) 737-7600, ext 6087. **Circle No. 403**



Four telecommunications ICs target personal communicators. The monolithic microwave chips are designed around a JFET process for the 1.9-GHz band and 3V operation. The CXG1002M $2.75 (100,000) is an antenna switch for transmitter and receiver signal switching. The CXG1003M $2.20 (100,000) is a low-noise amplifier for use with an external mixer. The CXG1004M $2.20 (100,000) is a mixer with low noise and high gain. The CXG1005MC $9.90 (100,000) is a linear power amplifier. **Sony Electronics Inc**, San Jose, CA. (800) 288-7669. **Circle No. 404**

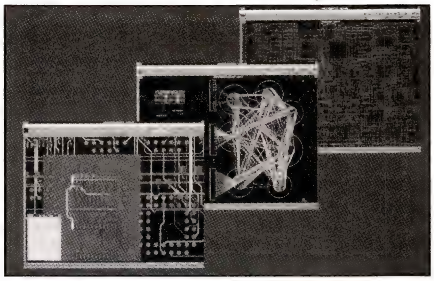
Electrometer-grade op amp available in low-cost package. The OPA129 op amp is available in 8-pin DIP and SO-8 packages. A 100-fA maximum input-bias current makes the op amp suitable for high-impedance sensors, low-drift integrators, pH-probe amplifiers, and ion-gauge measurements. Other specifications include a 2-mV max offset voltage, 10-μV/°C max drift, and 15-nV/√Hz noise level at 10 kHz. $3.15 (100). **Burr-Brown Corp**, Tucson, AZ. (602) 746-1111. **Circle No. 405**

Multifunction I/O-interface chip for PCMCIA operates on 3.3 or 5V. The PCM16C00 meets the proposed PCMCIA multifunction standard for PCMCIA-card designs. The circuit supports any two I/O functions and memory. Power-management features let you turn off or select sleep mode for one or both functions. The IC also supports hot-swapping, avoiding the need to reboot the system after changing PCMCIA cards. The IC comes in a 144-pin TQFP and costs $15 (1000). **National Semiconductor Corp**, Santa Clara, CA. (800) 272-9959. **Circle No. 406**

FREE INFO, FREE POSTAGE
Use our postage-paid reader-service cards to get more information on any of these products.

Dynamic system simulator features expanded tool-suite libraries. The SystemView simulator for high-level design and analysis of analog and digital systems now offers optional libraries for communications, DSP, and logic applications, as well as a user-definable extendible token library. The communication-library option provides a set of tools for designing and simulating communication systems. The model can include error-correcting codes, baseband pulse shaping, modulation, channel models, demodulation, error correction, and data recovery. Using the tool, you can produce bit-error-rate curves in a single run. The Windows-based simulator costs $2450. **Elanix Inc**, Westlake Village, CA. (818) 597-1414. **Circle No. 407**

FPGA and ASIC logic-synthesis tools accommodate hierarchical designs. The ViewSyn/FPGA and ViewSyn/ASIC logic-synthesis tools accept register-transfer-level, Verilog, and VHDL design descriptions. Both tools use the Motive static-timing engine. ViewSyn/FPGA includes optimization to vendor-specific field-programmable gate-array (FPGA) mapping and costs $8000 under Workview Plus and $10,000 under Powerview. ViewSyn/ASIC provides technology-independent and -specific optimization using vendor cell libraries. ViewSyn/ASIC costs $12,000 less than Workview Plus and $15,000 less than Powerview. Shipments will begin in the fourth quarter. **Viewlogic Systems Inc**, Marlboro, MA. (508) 480-0881. **Circle No. 408**



Company offers three versions of its pc-board design software. The MaxEDA product is now available in three versions. The Bronze edition ($2995 for Windows) offers interactive component placement and routing. The Silver edition ($5995 for Windows, $7195 for Windows NT) suits analog and RF pc boards. The Gold edition ($9550 for Windows, $11,460 for Windows NT) offers autorouting control and suits fast, high-density designs. **Massteck Ltd**, Littleton, MA. (508) 486-0197. **Circle No. 409**

Formal verification tool includes support for Vital Level 1 structural VHDL. The VFormal version 2.1 tool lets you verify whether two VHDL design descriptions are equivalent. The tool creates a formal mathematical proof that two synchronous VHDL descriptions are functionally equivalent for every set of legal inputs and internal states. Using the tool, you can find all the differences between a known-good implementation of logic and a new implementation. Available in the first quarter of 1995, the software will cost $60,000. **Compass Design Automation**, San Jose, CA. (408) 433-4880. **Circle No. 410**

FREE INFO, FREE POSTAGE
Use our postage-paid reader-service cards to get more information on any of these products.

Lightweight, high-resolution color display designed for the virtual-reality market. The EX100HD is a 1-in. display that uses the company's pi-cell technology and color shutters. The display's heads weigh 5.3 oz and have a spot size of less than 1.5 mils. The multiscaning display has a typical resolution of 640×480 pixels noninterlaced. You can configure the display to run at 1280×960 pixels interlaced. The monitor locks to any horizontal frequency of 60 to 120 kHz and any vertical frequency from 150 to 200 Hz. $9750. **Tektronix Display Products**, Beaverton, OR. (800) 835-9433 ext 5000.
Circle No. 411

Portable multimedia PC uses 90-MHz Pentium processor. The Regal/Multimedia/P90 has a 10-in.-active-matrix TFT color screen, 8 Mbytes of RAM, a 512-kbyte cache, a 420-Mbyte hard disk, a 1.44-Mbyte floppy-disk drive, a CD-ROM drive, a sound card, and speakers. $5699. **Micro Express**, Santa Ana, CA. (714) 852-1400.
Circle No. 412

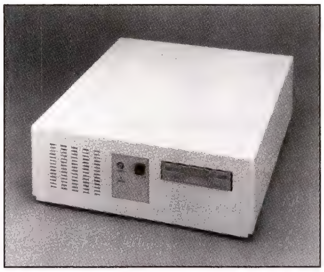
PCMCIA Ethernet adapter drops price to $249. The EA903 uses a Type II PCMCIA socket and is compatible with both 10BaseT twisted-pair and 10Base2 thin-coaxial cable. NE2000 compatibility lets the unit work with the certified drivers that are included with most network-operating systems. **Socket Communications Inc**, Hayward, CA. (510) 670-0300.
Circle No. 413

Multiprocessing SPARCstation-20-compatible workstations. The multiprocessing SuperCOMPstation 20A desktop and deskside workstations are available in four models. The 20A-502 MP workstation has dual 50-MHz SuperSPARC processors. The devices provide estimated performance of 69 SPECint92 and 78 SPECfp92 for each CPU. An entry-level desktop configuration starts at $13,370 and includes a 2-D/3-D TurboGX graphics accelerator, a 20-in.-color monitor, 32 Mbytes of RAM, and a 520-Mbyte hard drive. **Tatung Science & Technology Inc**, Milpitas, CA. (408) 383-0988.
Circle No. 414

CD-recorder operates at double speed. The CDD522 has a 2-Mbyte cache buffer that is upgradable to 32 Mbytes. The recorder meets Orange book standards and records and plays back at single or double speed for all CD formats including CD-ROM, CD-ROM (XA), CD-I, CD-Audio, CD-Bridge MultiSession, CD-Video, and Photo CD. The unit has a SCSI-2 interface and costs $3899. **Philips Laser Magnetic Storage**, Colorado Springs, CO. (719) 593-7900.
Circle No. 415

TCP/IP file-transfer software works with FTP. The NetWizard file-transfer software provides a graphical user interface, encryption, compression, access control, batch operation, and firewall support. The software works with SunOS 4.1.X, Solaris 2.X, and HP 9000/700 Series HP-UX 9.01. $495 until year-end, $995 after. **Microlink Technologies Inc**, Davis, CA. (916) 757-1180.
Circle No. 416

Data/fax modem with voice messaging on a single PCMCIA Type II card. The NovaModem 144 is a 14400-bps data/fax modem that comes with software for data, fax, voice, and wireless communications. The wireless software lets you send alphanumeric messages through paging services. The modem provides V.42 LAPM and MNP 2 to 4 error correction, V.42bis and MNP5 data compression, and MNP 10 for enhanced data throughput. $269. **NovaLink Technologies Inc**, Fremont, CA. (510) 249-9777.
Circle No. 417



ISA bus passive-backplane enclosure has four slots. The 4400 passive-backplane enclosure provides four full-length ISA expansion slots and space for three 3.5-in. peripherals. The enclosure has filtered-, forced-air cooling and a 100W power supply. All configurations are UL, CSA, and FCC compliant and have a two year warranty. $232 (OEM). **I-Bus division of Maxwell Laboratories**, San Diego, CA. (619) 569-0646.
Circle No. 418

Printer sharing devices work with six LAN operating systems. The Netjet and Netque printer-sharing devices allow workstations on networks using different protocols to have direct access to the same printers. The devices support IBM's LAN Server, Microsoft's LAN Manager, Novell Netware, Apple EtherTalk, Digital-licensed LAT, and UNIX-TCP/IP. Netjet works with HP printers or plotters and costs $499. Netque works with any printer or plotter and costs $599. **Emulex Corp**, Costa Mesa, CA. (714) 662-5600. **Circle No. 419**

Server-based frame-relay technology. The Universal Frame-Relay Access Device (UFRAD) uses a network-interface card and frame-relay software to let a Unix-based application server provide multiprotocol frame-relay access and switching along with point-to-point protocol (PPP) access. The technology is available for Sun Sparc and Solaris x86 computers. Costs range from $2560 to $4495. **Adax Inc**, Berkeley, CA. (510) 548-7047.
Circle No. 420

Flash-file system supports FFS and FTL PCMCIA-approved standards. Manufacturers of PCMCIA products need flash-file system software that is compatible with FFS and FTL standards to provide the greatest system flexibility. CardTrick works with both and costs $6 (500) to $1.50 (25,000). **Datalight**, Arlington, WA. (206) 435-8086.
Circle No. 421

Worldwide
Olympic Sponsor

UPS Standard *UPS Expedited* *UPS Express*

How small a continent do you want to make it?

UPS just made doing business in North America more manageable than ever before. Because depending on your schedule and budget, you can now choose between three levels of door-to-door service from the United States to either Canada or Mexico: from Standard to Expedited to overnight Express. All of which offer tracking, customs clearance and shipment pricing.

Just tell us when your packages need to get there and we'll be happy to adjust the size of the continent accordingly. For more information on how we can tailor North America for you, simply call us at 1-800-PICK-UPS. **The package delivery company more companies count on.**℠

UPS®

CIRCLE NO. 107

FREE INFO, FREE POSTAGE
Use our postage-paid reader-service cards to get more information on any of these products.

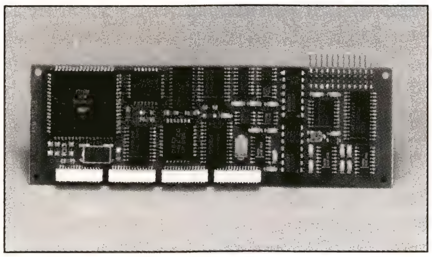
Shareware utility libraries for assembly and Basic languages. The ASM Utility library has 503 public domain and shareware products for assembly language programmers. The VBDOS/QB/PDS Utility library has 253 public domain and shareware Basic-language products for programmers using Visual Basic for DOS, Quick Basic, and PDS. Each library costs $59.50 and is available in either 1.44-Mbyte disks or CD-ROM. **EMS Professional Shareware**, Olney, MD. (301) 924-3594.
Circle No. 422

Low-cost microcontroller board based on the PIC16C5X. The SXT-55 costs $124.95 and accommodates PC-XT 8-bit type I/O modules. The microcontroller board is designed for stand-alone applications that can't use a PC host because of cost, size, or power restrictions. In addition to two PC bus connectors, the board has programmable switches and LEDs, TTL-level input and output lines, and interface circuitry for direct connection to industry-standard LCD displays. **Unified Microsystems**, Slinger, WI. (414) 644-9036. **Circle No. 423**

DSP boards for ISA and PCI buses have DSP56002 24-bit fixed-point DSP. The Eagle-56 is available in 40- and 66-MHz versions and is designed for speech processing, digital audio, and multimedia applications. The board provides four banks of 64k×24-bit zero wait-state SRAM, two 16-bit stereo Codecs, and high-speed parallel host interfaces. The board is capable of independent operation for embedded applications. Including Windows-based debugger, loader, and test utilities, the 40-MHz version is $2695, and the 66-MHz version costs $3695. **Momentum Data Systems Inc**, Costa Mesa, CA. (714) 557-6884.
Circle No. 424

Development tools and real-time operating system for Intel386 and AMD Am386EM µPs. Development tools, including the Xray debugger, C compiler, assembler, Xray Masterworks environment, and the Spectra open cross-development backplane, are now available for the Am386EM and 486SE and the Intel 386 µPs. The VRTX 3.0 real-time operating system costs $2000. The complete development toolkit is $9000 on a Sun and $3850 on a PC. **Microtec Research Inc**, Santa Clara, CA. (408) 980-1300. **Circle No. 425**

Integrated controller and disk drives for the STD 32 bus. The ZT 8952 has an integrated IDE controller and a 130-Mbyte hard disk drive, that all fit in a single STD 32-backplane slot. The unit costs $550 (or $225 without the disk drive installed). The ZT 8954 is an integrated 1.44-Mbyte 3.5-in. floppy disk drive and controller that also fits in a single STD 32-backplane slot. The unit costs $345 ($255 without the floppy drive). **Ziatech Corp**, San Luis Obispo, CA. (805) 541-0488.
Circle No. 426



A/D and D/A modules fit 1.7×5.2-in. format. The Extremely Small Package (ESP) form factor the company has developed for PC/XT/AT systems now includes an analog-to-digital module with eight differential or 16 single-ended inputs, 12 bit resolution, a 333-kHz throughput, and a programmable gain amplifier. $333 (100). A digital-to-analog module with 24 8-bit DACs, two 12-bit DACs, eight TTL-level I/O channels, and a sine and square wave generator costs $316 (100). **Dovatron International Inc**, Longmont, CO. (303) 772-5933. **Circle No. 427**

$99 design kit lets you experiment with a DSP for real-time signal processing. The TMS320C5x DSP Starter Kit (DSK) combines the TMS320C50-based board with an assembler and debugger to provide a development system for benchmarking and evaluating code in real time. The board includes a 40-MHz TMS320C50 DSP with 10k words of on-chip RAM, a TLC32040 analog-interface chip with 14-bit A/D and D/A, an RS-232C serial port for communicating with a PC, and other features. **Texas Instruments Inc**, Denver, CO. (800) 477-8924 ext 4500.
Circle No. 428

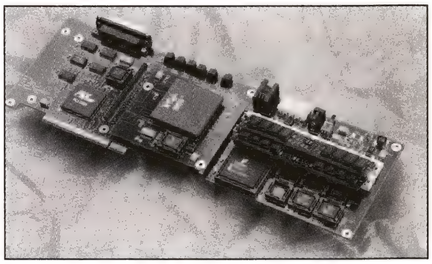
486SLC-based VMEbus board offers flexibility and economy for embedded PC systems. The PC AT-software-compatible VSCIM486SLC board suits industrial and real-time applications. Available in both standard and 50-MHz clock-doubled versions, the board provides space for a math coprocessor, up to 16 Mbytes of DRAM, 4 Mbytes of flash EPROM, 512 kbytes of dual-ported SRAM, floppy-disk and IDE hard-disk controllers, a keyboard interface, two serial ports, a parallel port, a battery-backed real-time clock, a watchdog timer, and a counter/timer. A 256-byte EEPROM provides nonvolatile retention of BIOS configuration data and other information. The board with 2 Mbytes of DRAM starts at £1143(10). **Arcom Control Systems Ltd**, Cambridge, UK. +44 (0)223 411200. **Circle No. 429**

C source-code debugger runs on PCs under Windows. The TMS320C2x symbolic debugger provides source-code debugging for C- and assembly-language code. The software works with the Texas Instruments XDS/22 emulator and has a profiling capability that shows the time parts of a program consume. The debugger lets you set hardware breakpoints, count events, collect trace samples, start and stop timers, qualify cycles, monitor external signals, and perform complex timing analysis. $995. **Hyperception**, Dallas, TX. (214) 343-8525. **Circle No. 430**

Industrial PCXI computer chassis suits high-vibration environments. The PCXI model 1101 13-slot industrial-computer chassis features front-access shielded-metal modules and a choice of AT or EISA bus passive-backplane and single-board CPU combinations. The unit has two rear-mounted 72CFM filtered-intake fans providing positive pressure cooling. Front-panel, quick-release, hold-down screws reduce vibration and protect internal components. $1795. **Rapid Systems Inc**, Seattle, WA. (206) 784-4311. **Circle No. 431**

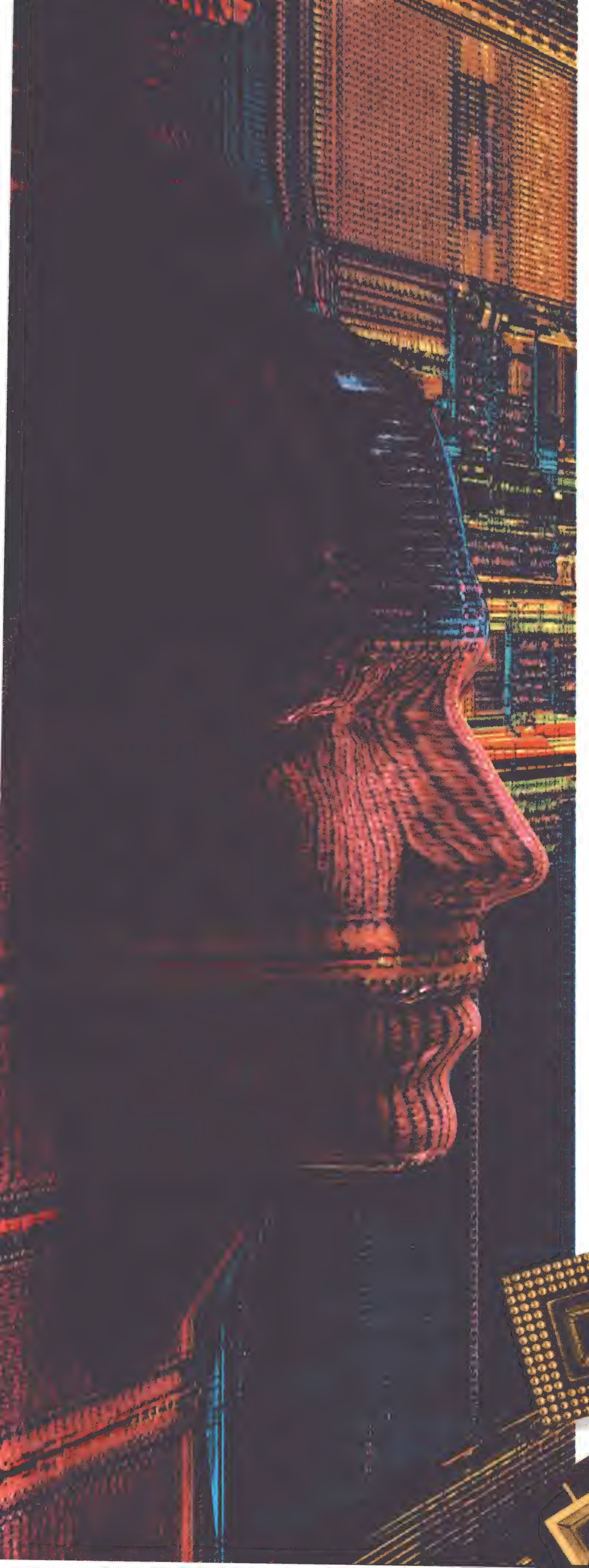
Low-cost computer module suits embedded-μC market. The CoreModule/PC ($99 (1000)) has a 9.8-MHz 8088-compatible CPU, capacity for 1 Mbyte of DRAM, serial- and parallel-port controllers, a keyboard port, a watchdog timer, an optional solid-state disk, and a speaker interface. The computer module uses inexpensive, simple, PC-compatible software to develop applications and thus is not limited to proprietary μC architectures. The palm-sized module draws 0.6W from 5V when operating and 0.3W in sleep mode. **Ampro Computers Inc**, Sunnyvale, CA. (408) 522-2100. **Circle No. 432**

SBus boards for graphics, serial ports, and SCSI. The TurboGX graphics accelerator ($1495) is compatible with screen resolutions of 1152×900 and 1024×768 pixels. The card accelerates 2 and 3D vector rendering and windows and works with Solaris and Sun OS applications. The FastSerial-4 board provides serial data transmission up to 230.4 kbps and is available in four-, eight-, 16-, and 24-port versions. The ports use standard 25-pin D connectors and come with full modem controls. A four-port board costs $485, and a 24-port board costs $2495. The SCSI-FNS II adapter ($545) lets you connect seven SCSI devices. The adapter provides active terminations to accommodate cable lengths of more than 20 ft. **Antares Microsystems Inc**, Los Gatos, CA. (408) 370-7287. **Circle No. 433**



I/O processor for the PCI bus uses i960CF μP. The PCI960 board uses a plug-in processor module, allowing the board to use any member of the i960 processor family and to operate as fast as 40 MHz. Modules are also available for Ethernet, high-speed serial, SCSI-2, SCSI-3, and parallel interfaces. With a 33-MHz i960CF, the board costs $1825 (100). **Cyclone Microsystems**, New Haven, CT. (203) 786-5536. **Circle No. 434**

MIPS 64-bit single-slot computer for Futurebus+. The FBR4400 uses an R4400SC RISC processor and can sustain 90 VAX MIPS operations and 30 MFLOPS. The DMA burst rate is 160 Mbytes/sec. The device offers onboard capacity for up to 128 Mbytes of RAM, an external cache of up to 4 Mbytes, 512 kbytes of flash boot EEPROM, 8 kbytes of nonvolatile RAM, and a real-time clock. $7995. **Cable & Computer Technology Inc**, Anaheim, CA. (714) 937-1341. **Circle No. 435**



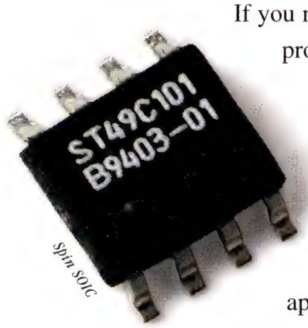
INTRODUCING OUR NEW HIGH SPEED OSCILLATOR CHIP.

It can be customized.

Costs half as much

Uses half the space.

And is deliverable in three weeks.



And fast? We're talking up to 160MHz. If you need oscillator chips for your products, you need to know about Startech's new ST49C101. The industry's first mask programmable monolithic analog CMOS device. It's an inexpensive solution for industrial applications, especially in the area of high speed electronics such as mobile computing.

Say goodbye to yesterday's costly and inflexible standards.

We literally custom design the circuit board for you. With prices running as low as $3 per unit, there's nothing else to buy.

Offering either a high-end crystal or oscillator chip solution, Startech's ST49C101 can be ordered in 8-Pin DIP and SOIC packages.

We can deliver to you in three weeks. But first things first. You've got to make the call. Do it today.

For more information, call (408) 745-0801 or fax us at (408) 745-1269. For evaluation boards on our products, call (800) 245-6781.

PRODUCT NUMBER	DESCRIPTION	PACKAGE
Frequency Generators		
ST49C107	Mother Board Clock Up To 2 Outputs	8,14 PDIP/SOIC
ST49C155	Mother Board Clock Up To 8 Outputs	20 PDIP/SOIC
ST49C214	Dual Clock Output Up To 20 Freqs.	20 PDIP/SOIC
ST49C104	Single Clock Output	8,14 PDIP/SOIC
ST49C154	Mother Board Clock	16 PDIP/SOIC
Drivers/Receivers		
ST31C32	3,5 RS422/423 Transceiver	28 PDIP/SOIC/PLCC
ST34C87/26C31	Quad RS422 Differential Line Dr.	16 PDIP/SOIC
ST3486/26C32	Quad RS422/423 Differential Line Rec.	16PDIP/SOIC
ST34C50/34C51	Dual RS422/423 Transceiver	16 DIP/SOIC
UARTS		
ST16C550	UART w/FIFO	40 PDIP/44 PLCC
ST16C552	DUART w/FIFO/Printer	68 PLCC
ST16C553	DUART w/FIFO/Printer w/FIFO	68 PLCC
ST16C2550	DUART w/FIFO	40 PDIP/44 PLCC
ST16C554/68C554	Quad UART w/FIFO	68 PLCC
Peripherals		
ST37C65	Floppy Controller	40 PDIP/44 PLCC
ST78C34	Printer w/FIFO	40 PDIP/44 PLCC

Free data book available on request.

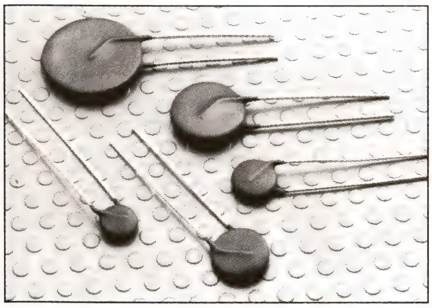
STARTECH
SEMICONDUCTOR, INC.
1219 Bordeaux Drive, Sunnyvale, California 94089
Phone: (408) 745-0801 Fax: (408) 745-1269

CIRCLE NO. 206

FREE INFO, FREE POSTAGE
Use our postage-paid reader-service cards to get more information on any of these products.

SOIC-to-DIP adapter fits 28-pin SOIC packages within the DIP layout. The adapter is 0.300 in. wide with 0.100-in. pitch and has surface-mount pads on top to accept a 0.050-in.-pitch SOIC. $4 (100). **Aries Electronics Inc**, Frenchtown, NJ. (908) 996-6841. **Circle No. 436**

SOIC-to-DIP adapter fits 28-pin SOIC packages within the DIP layout. The adapter is 0.300 in. wide with 0.100-in. pitch and has surface-mount pads on top to accept a 0.050-in.-pitch SOIC. $4 (100). **Aries Electronics Inc**, Frenchtown, NJ. (908) 996-6841. **Circle No. 437**



Inrush-current-limiting thermistors are low-cost. The ICL series of inrush-current-limiting thermistors cost $0.24 to $0.18 (5000 to 100,000). The devices are available in resistance values of 0.5 to 220Ω and tolerances of 5 to 30%. The thermistors suit circuit-protection and control applications, including switching power supplies and power-factor-correction circuits. **Fenwal Electronics Inc**, Milford, MA. (508) 478-6000. **Circle No. 438**

Pin-strip headers cost $0.02 per pin. The 2300 series pin-strip headers have a 10-μm gold and gold-flash plating on phosphor-bronze pins. The glass-filled polyester insulation lets you break the headers to length, allowing you to stock one size in inventory. The headers are available in single- and dual-row versions having straight or right-angle configurations. Solder standoffs simplify washing off the flux residue after soldering. The headers stack side by side or end to end. **3M Electronic Products Division**, Austin, TX. (800) 225-5373. **Circle No. 439**

Dual PNP complementary transistor pairs are QPL-approved. The JANTX2N5796U and JANTXV2N-5796U transistor pairs are QPL-approved in accordance with MIL-S-19500/496. The device comprises two PNP transistors, similar to the 2N2907, mounted in a six-pin hermetic, ceramic, surface-mount package. From $12.97 (1000). **Optek Technology Inc**, Carrollton, TX. (214) 323-2200. **Circle No. 440**

Ceramic surface-mount capacitors have 500V rating. The capacitors are available with X7R or COG characteristics and operate in circuits in which continuous or peak voltages may reach 500V. The X7R capacitors are available in 1206, 1210, and 1812 sizes, with capacitance ranging from 470 pF to 15 nF and tolerances of ±5, ±10, and ±20%. The COG capacitors are available in 1206, 1210, and 1812 sizes, with capacitance ranging from 10 to 1000 pF and tolerances of ±2, ±5, and ±10%. Prices range from $0.0265 to $0.124. **Philips Components**, Riviera Beach, FL. (407) 743-2102. **Circle No. 441**

Surface-mount inductors have low-resistivity ferrite core. The SM20 series inductors suit switching-power-supply applications and are available in values from 10 μH to 1 mH. Custom values and tolerances are available. The operating temperature range is –55 to +125°C. <$2 (1000). **Gowanda Electronics**, Gowanda, NY. (716) 532-2234. **Circle No. 442**

RF transistors for 2.7V operation increase battery life in portable systems. The AT-30511, AT-30533, AT-31011, and AT-31033 work between 1 and 5V with as little as 0.5 mA of current. The transistors suit low-noise amplifiers, gain stages, buffers, oscillators, active mixers, and other high-frequency applications in battery-operated equipment, such as pagers, handheld telephones, wireless-LAN terminals, and RF tags. The AT-30533 provides 14-dB gain and a 1.2-dB noise figure at 900 MHz when biased at 2.7V, 1 mA. From $0.53(1000). **Hewlett-Packard Co**, Santa Clara, CA. (800) 537-7715 ext 8758. **Circle No. 443**

EDN PRODUCT MART

This advertising is for new and current products.

Please circle Reader Service number for additional information from manufacturers.

ROM-IT
EPROM EMULATION SYSTEM

The Most Flexible EPROM Emulator You Can Get Today

- Emulates up to eight 4-Megabit EPROMS through one standard serial port.
- Downloads 2-Megabit programs in less than 23 seconds
- Examine and modify individual bytes or blocks.
- Accepts Intel Hex, Motorola S-Record and Binary files.
- Software available for IBM PC and compatibles.
- Base 27256 EPROM System **$395.00**. Other configurations available.

Incredible Technologies, Inc.
Visa, Mastercard and American Express Accepted

Order Now - It's Easy
Call (708)870-7027 Or Fax (708)870-0120
For More Information

CIRCLE NO. 246

In-Circuit Emulators For
8051
683xx
68HC11
68HC16
80C196

See EEM 94/95 Pgs. D1288-1294

- Rental and 10-day trials available.
- Full Source-level Debugger with *complete* C-variable support.
- Supports virtually all members of the 8051, 80C196, 68HC11, 68HC16 and 68300 families.

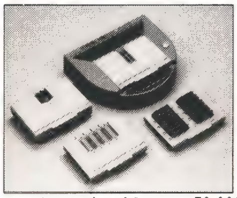
CALL OR WRITE FOR FREE DEMO DISK!

NOHAU CORPORATION
51 E. Campbell Ave.
Campbell, CA 95008
FAX (408) 378-7869
TEL (408) 866-1820

Call 408-378-2912
Nohau's 24-hour information center to receive info via your FAX

CIRCLE NO. 254

UNIVERSAL/GANG PROGRAMMERS



FLEX-700

48 pin from	$945
40 pin from	$845
8 gang from	$845
TUP-400	$645
TUP-300	$495

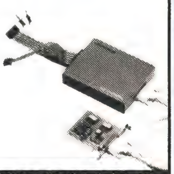
Appreciated by over 70,000 users worldwide

- Supports Altera 7xxx, MACH 435, Xilinx, Intel FX7xxx, nearly all FPGA/CPLD/PLD...
- Support EPROM, 28/29F flash, serial PROM, PSD4XX/5XX, Intel/Motorola/NEC/Hitachi MPU devices. Over 3,000 devices supported.
- Test TTL 74/40/45 series, DRAM(SIP/SIMM), and SRAM. EPROM EMULATION option.
- Gang programming & stand alone option.
- Universal 44,68 pin PLCC modules.

8051 IN-CIRCUIT EMULATORS
NICE-51 SYSTEMS FROM $895

- Supports 87(C)51 and many derivatives.
- Fully supports emulation of internal and external memory with no intrusion on user memory, I/O, stack, INT...
- Supports Archimedes, Franklin, Intel, IAR, KEIL, 2500AD,... C compilers and most assemblers.
- Single step, go slow, run in real time, set break-points and much much more...
- Complex trigger and filter functions let you trace in real time all or any portion of program execution you desire (up to 16K 48bit words).

ROM/RAM EMULATORS
TRE/EML SYSTEMS FROM $295



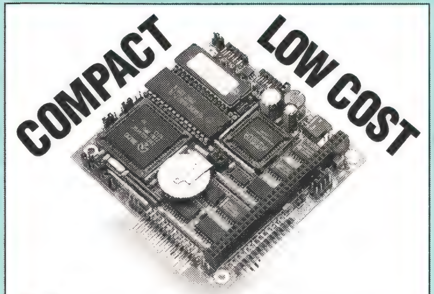
- Emulate up to two 27(C)64 - 27(C)010 devices at one time in independent or 16 bit even/odd mode.
- Emulate one 27C020, 27C1024, 27C2048.

EPROM PROGRAMMER FROM $145

Tribal Microsystems Inc.
44388 S. GRIMMER BLVD., FREMONT, CA 94538
Tel: (510) 623-8859
Fax: (510) 623-9925

CIRCLE NO. 261

COMPACT LOW COST



C-Programmable Controllers
Use our controller as the brains of your next control, test or data acquisition project. From $149 qty one. Features I/O to 400 lines, ADC, DAC, RS232/RS485, printer port, battery-backed clock and RAM, keypads, LCDs, enclosures and more! Our simple, yet powerful, Dynamic C™ makes programming a snap!

24-Hr AutoFAX: 916.753.0618.
Call from *your* FAX.
Request catalog 18.
1724 Picasso
Davis, CA 95616
916.757.3737
916.753.5141 FAX

Z WORLD ENGINEERING

CIRCLE NO. 266

PROTO EXPRESS
Best Value in the World
for
POLYIMIDE & FR4
1 to 5 DAY TURN
1 to 12 Layers
PRINTED CIRCUIT PROTOTYPES

2 PIECE PRICES FOR FR4 .062 Th.

LAYERS		1	2	3&4	5&6	7&8
SQUARE INCH UP TO	15	$233	$292	$639	$787	$935
	30	264	330	724	891	1059
	60	311	389	853	1049	1137
	90	358	448	980	1207	1434
	120	385	486	1044	1311	1559

- 5 PIECES x 1.34
- 10 PIECES x 1.67
- 5 DAY PRICES ABOVE
- UL LISTED

EXTRAS
- Photo Plotting
- Testing
- Gold Contacts - $50
- 25% - Below 8 Mil Hole
- - Below 15 Mil Hole
- SMOBC & LPI - $50

CAPABILITIES
- Buried & Blind Vias
- Polyimide Multilayer
- Full Body Gold
- Carbon Paste
- Tin nickel burn-in boards
- SMT-SMOBC
- Up to 22 layers
- Impedance control boards

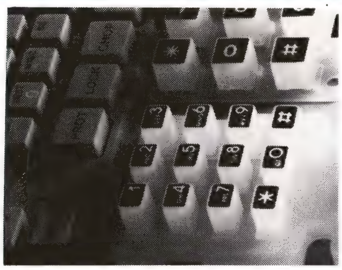
DISCOUNTS
- VISA / MasterCard 5%
- COD 10%

FOR MORE INFORMATION CALL OR FAX

Ken Bahl ■ 1108 W. Evelyn Ave., Sunnyvale, CA 94086
Phone (408)735-7137 FAX (408)735-1408 Modem (408)735-9842

CIRCLE NO. 256

To advertise in Product Mart, call Joanne Dorian, 212-463-6415



Only a Specialized Keypad Manufacturer Could Provide Versatile and Economic Products.

With more than 11 years of experience in this field, we proudly offer you various types of conductive silicone rubber pads, rubber pads with multicolor keys and multicolor printing, translucent parts for backlighting. Please contact us early for design assistance and information.

GENERAL SILICONES CO., USA
650 W. Duarte 401 Arcadia CA 91007, USA
Tel: (818) 445-6036 Telex: 3716189 GSCUI
Fax (818) 445-6084

CIRCLE NO. 243

Get Rid of The Bugs, On The Fly.

SIGNUM IN-CIRCUIT EMULATORS
80196 • 8051 • 80186 • Z8
DSP • HPC • 8085 • Z380

REAL-TIME IN-CIRCUIT DEBUGGING & DEVELOPMENT
ON-THE-FLY ACCESS TO PROGRAM AND DATA MEMORY
REAL-TIME TRACE FILTERING
FREE! 10-DAY TRIAL TRY BEFORE YOU BUY
EXTERNAL UNIT WITH NO PLUG-IN CARDS
FREE USER SUPPORT
OUTSTANDING PERFORMANCE AT A REALISTIC PRICE

SIGNUM SYSTEMS
FOR MORE INFO OR TO ARRANGE YOUR 10 DAY FREE TRIAL, CALL:
1-800-838-8012

CIRCLE NO. 257

Right on Target...
EMULATOR for the TMS 320C3X at less than ½ price!

* *Top-ranking multilevel debugger*
* *Power-packed command set*
* *User-friendly*
* *Target emulation via JTAG*

8 Shaul HaMelech Blvd.
Tel Aviv 64733, Israel.
Fax 972-3-693-8441

EMUTEC

CIRCLE NO. 242

NEW! SCANTEAM® 3400 CCD

WELCH ALLYN INTRODUCES THE SCANTEAM® 3400 HAND HELD CCD SCANNER

The ST3400 features:
- Unique CCD optics for superior first-read rate
- Depth of field up to four inches
- Ability to read bar codes wider than scan head
- Ergonomic pistol grip
- Optional integrated decoder interface
- High durability/no moving parts

For more information on how the ST3400 can solve your scanning needs, contact:

Welch Allyn
Data Collection Division - OEM Sales
4619 Jordan Road
Skaneateles Falls, NY 13153
Phone **(315) 685-8945** FAX **(315) 685-3172**

CIRCLE NO. 263

486 Single Board Computers & Rack Mounts

3 YEAR WARRANTY

intel inside

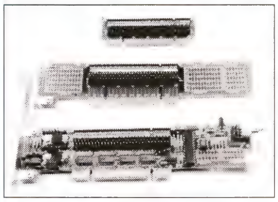
8 Slot 486SX-25 4MB 170MB HDD $1,495.00
14 Slot 486DX-33 4MB 250MB HDD $1,995.00
20 Slot 486DX2-66 4MB 540MB HDD . . .$2,495.00
PLEASE CALL FOR CUSTOM CONFIGURATIONS.

ORDER DESK 1-800-777-4875

US LOGIC **Made In U.S.A.**
5055 Viewridge Ave., San Diego, CA **92123**
(619) 467-1100 • FAX (619) 467-1011
The Intel Inside Logo is a registered trademark of Intel Corporation.
3 year warranty applies to Falcon-II Single Board Computer.

CIRCLE NO. 262

PCI BUS EXTENDER and BUS ISOLATION EXTENDER



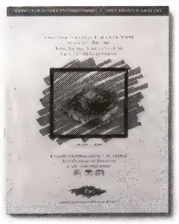
5.0 VIO
3.3 VIO
Four Models
Hundreds Sold

Speed up your PCI product development and testing time using the best featured and best valued PCI Bus Extenders and Bus Isolation Extender.

Call now for more information.

Adex Electronics
22994 El Toro Road **Tel: 714-768-3211**
Lake Forest, CA 92630 **Fax: 714-472-9654**

CIRCLE NO. 230



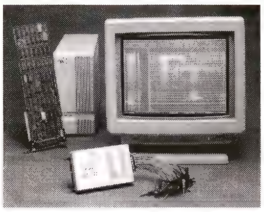
#1 in Adapter Solutions for over 10 years

FREE 1994 Interconnect Solutions Catalog

✓Over 3,500 devices for one-stop-shopping
✓120 "Off-the-shelf" items available for overnight delivery
✓Unlimited application consulting
✓Time saving solutions for product development
✓Ask about our custom designs
✓Leading edge technology -- over 500 PQFP solutions

EMULATION TECHNOLOGY, INC.
800.995.4381

CIRCLE NO. 240



Rated #1 for Ease-of-use by OEMs & end users

Expandable Logic Analyzer *plus*

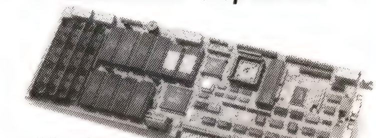
✓50 MHz and 25 MHz state and timing
✓32K sample depth, up to 192 channels
✓Professional features in PC-based product
✓Easy-to-use, windows-like interface
✓PC-based desktop and ISA bus versions
✓Digital/analog pattern generator option

EMULATION TECHNOLOGY, INC.
800.995.4381

CIRCLE NO. 241

THINK CPU
THINK MCSI

"The Embedded PC Specialists"



- Full line of ISA CPU boards through DX4/100
- PC/104 expansion port
- Integrated PROMDISK® disk emulator supports Flash, EPROM, & SRAM.
- Performance ranges from PC/XTs to 66MHz 486
- Half size and full size boards available

Also Available
- 3 to 14 Slot Backplanes and Embedded Chassis
- Full Line of PROMDISK disk emulator boards

MCSI
2598 fortune way
vista, ca 92083
619/598-2177
fax 619/598-2450

CIRCLE NO. 251

To advertise in Product Mart, call Joanne Dorian, 212-463-6415

High Density Circular Process and Medical Equipment Connectors

D Series 7, 9 and 12 contact cable to cable and chassis connectors provide MIL quality contacts in impact resistant Polycarbonate housing. Keyed simple push button lock minimizes use problems. Solder cup or crimp contacts are useable in either housing.

FOR ADDITIONAL INFORMATION, CONTACT:
HYPERTRONICS CORPORATION
16 Brent Drive, Hudson, Massachusetts 01749
(800) 225-9228 or (508) 568-0451
FAX: (508) 568-0680

CIRCLE NO. 245

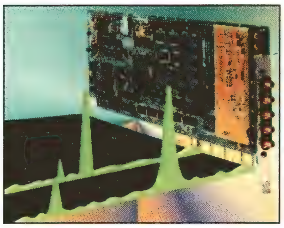
Advin

PILOT-U84 Universal Programmer

#1 in New Device Support & Expandability

Altera 7064,7128,7160,7192 in 84-, 100- and 160-pin packages
Xilinx 1765D,17128 etc Intel FLEX, 87C196 KC,KD,JR,MC etc.
Moto 68HC711, 68HC705, WSI PSD-3XX,-4XX,-5XX,PAC,SAM
Atmel 29C040, ATF22V10 etc. AMD MACH435, 29F040, etc
Lattice pLSI-1000,2000,-3000. Microchip PIC micros
All packages to 256-pin: PLCC,PGA,QFP,TQFP,TSOP,SOIC
800-627-2456 FAX:(408) 736-2503, Sunnyvale, CA.

CIRCLE NO. 231



EISA 12/14-BIT A/D BOARDS STREAM DATA TO MEMORY AT 10MHZ

The PC-415 Family of EISA-based A/D boards gives VME+ performance at PC-based costs! 8 different pluggable A/D modules offer 12-14 bit resolutions, sample rates to 10MSPS, up to 16 input channels, SE/DE inputs and simultaneous sampling options. Extensive software support complements hardware features such as banked-FIFOs (to 8k), circular buffer memory and various clocking modes.

DATEL, Inc.
11 Cabot Boulevard • Mansfield, MA 02048
(508) 339-3000 • (800) 233-2765
FAX (508) 339-6356

CIRCLE NO. 237

RELIABILITY PREDICTION SOFTWARE

ARE YOUR PRODUCTS RELIABLE?

The RelCalc 2 Software Package automates the reliability prediction procedure of MIL-HDBK-217, or Bellcore, allowing quick and easy reliability analysis of electronic products on your PC. Say goodbye to tedious, time consuming, and error prone manual methods!

- NEW UPDATE! VERSION 3.1 now available.
- User friendly: pop-up menus, hypertext help.
- Very easy to learn and use; quick data entry.
- Part library for rapid recall of part data.
- Global editing functions for what-if? trials.
- Reports which clearly organize results.
- Save time & money as you design for quality.
- Try our Demo Package today for $25.

T-Cubed Systems, 31220 La Baya Drive, Suite 110, Westlake Village, CA 91362
CALL: (818) 991-0057 FAX: (818) 991-1281

CIRCLE NO. 259

LOGICAL

Has a Full Range of High Quality Universal & Gang
(EEPROMs, FLASH, PLD, & MICRO CONTROLLER)
Programmers

LOGICAL DEVICES, INC.
TEL: (305) 428-6868
FAX:(305) 428-1811
digelec

1 800 331-7766 Ext: 103

CIRCLE NO. 250

Macintosh Users!

ELECTRONIC DESIGN TOOLS

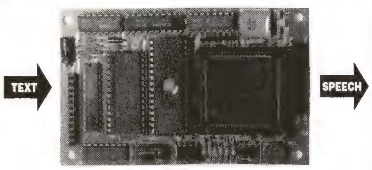
Capilano Computing is the source for quality electronic design tools for the Apple Macintosh®. Contact us for schematic capture, simulation (digital, analog and mixed-mode), PLD and FPGA design, PCB design, RF design and timing analysis tools. Using our DesignWorks™ schematic capture front end, you also get full file compatibility between Macintosh and Windows versions.

CALL (800) 444-9064
FOR YOUR FREE DEMO!

CAPILANO COMPUTING
(604) 522-6200 Fax (604) 522-3972

CIRCLE NO. 233

IMAGINE IF YOUR PRODUCT COULD TALK!



V8600 text-to-speech synthesizer

- Converts plain ASCII text into speech ("talking printer")
- Requires only a single 5V supply and speaker
- Unlimited vocabulary—*no custom recording necessary*
- Programmable pitch, rate, tone, volume, etc.
- Text, character, phonetic, tone and PCM modes
- Microprocessor, serial and printer interfaces
- Use in telecom, robotics, monitoring systems, etc.
- Less than $100 in OEM quantities
- ISA, PC/104 and stand-alone versions available

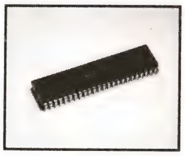
FREE V8600 DATA BOOK
USA Ph: 206 355-3800 Fax: 355-1098
UK/Europe Ph: +4481 539 0285

RC SYSTEMS INCORPORATED

RC Systems, Inc • 1609 England Avenue • Everett, WA 98203 USA

CIRCLE NO. 255

Talk Is Cheap,
Even Digitally.℠



MODEL: VP1410

- **QuikVoice™** technology
- Plays up to 10 messages stored in external EPROM
- 10 direct-trigger pins
- CVSD encoding
- 3 - 6V single supply
- DIP or surface-mount
- Low cost

Let your product speak for itself!

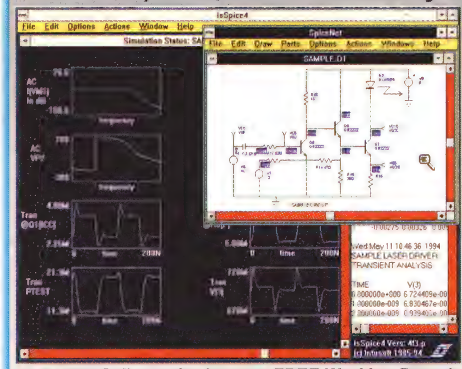
Our **QuikVoice** family of digital voice boards and IC chips give your product the competitive edge by letting them talk in real voice. Imagine how much more "user friendly" your product will become! Conventional voice technology requires high tooling cost and long turn-around time, while **QuikVoice** technology allows you to create a voice EPROM in just minutes with low-cost in-house equipment! Change messages easily or customize messages for each of your customers!

ELETECH ELECTRONICS, INC.
16019 Kaplan Ave, Industry, CA 91744 (818) 333-6394

CIRCLE NO. 239

Low Cost Analog Simulation

ICAP/4Lite, Schematic Entry and SPICE for Under $600



ICAP/4Lite, features schematic entry, powerful analog and mixed signal simulation, and extensive device libraries, all integrated in one easy to use environment. With ICAP/4Lite you can simulate all types of designs including Power, ASIC, RF, Mixed Mode, Control Systems, and Mixed Technologies.

Forget those other low cost systems They Can't Compare to ICAP/4Lite...

- *SPICE 3F based Simulator* - AC, DC, Transient, Temperature, Operating Point
- UNLIMITED CIRCUIT SIZE
- Integrated Schematic Entry
- High Performance 32-bit Simulator
- Real time waveform display
- Over 500+ Models Included
- Inexpensive upgrade path
- Windows and Windows NT
- Affordable Prices - $595

Call or write for your FREE Working Demo!
intusoft P.O. Box 710 San Pedro, CA 90733-0710
Tel. 310-833-0710 Fax 310-833-9658

CIRCLE NO. 248

REMOVE HARDWARE LOCKS

PROTECT YOUR INVESTMENT!
MAINTAIN PRODUCTIVITY!
Software utility that allows for the removal of hardware locks.

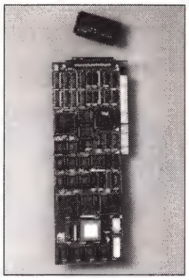
Available for most major CAD/CAM and PCB software programs

Easy - Simple - Guaranteed

Programs start at $99.00 U.S.
Visa and Mastercard Welcome
Call or Fax for more Information

SafeSoft Systems Inc.
201-1111 Munroe Ave.
Winnipeg, Mb. R2K 3Z5
Canada
Phone (204) 669-4639
FAX (204) 668-3566

CIRCLE NO. 258



PC-EISA TO ENCORE HSD DATA LINK/EMULATION

Using our PCEHSD® card and file transfer software, files can be moved between a PC EISA bus computer and an Encore computer HSDII board. The PCEHSD also emulates the HSDII; therefore, the PCEHSD can drive a HSDII compatible peripheral device. Transfer rates in excess of 10Mbytes/second. DOS I/O routines and interactive test program, and UNIX driver available. This product is an excellent tool for hi-speed data acquisition, monitoring or product test fixture.

APPLIED DATA SCIENCES, INC.
P.O. Box 814209, Dallas TX 75381-4209
(214) 243-0113 • FAX (214) 243-0217

CIRCLE NO. 232

Analyze FACSIMILE

T.30, T.4 & T.6 performance up to 14.4 Kb. Commented analyzes with corrections suggested. Simulate calls with included test libraries, write your own, or capture real-world calls for play-back.

Used in Design, Q.C., Mfg., & Service.

Call today for product information or application assistance.

GRAY ASSOCIATES
(408) 251-0263

Simulate

CIRCLE NO. 244

Combine your Product Mart ads in EDN Magazine and Products Editions for *higher impact* and a *lower rate!*

CIRCLE NO. 267

QFP and SOIC SMT Adaptors for Emulators and Logic Analyzers

- Two part modular construction
  - 62 mil high generic base replaces the chip variety of tops can be purchased separately, e.g. emulator, logic analyzer, ZIF socket, cable, etc. tops
- Easy to solder
  - 160 leads under 1 minute
  - no special equipment or experience required
- Rugged construction, minimum size, short traces
- Vertical extensions available
- Deliveries from stock to 3 days on most products

EDI Corp.
2611 Highland Drive, Las Vegas, NV 89109
Tel.: 702/735-4997, Fax: 702/735-8339

CIRCLE NO. 238

HiWIRE II

Schematic and PCB Software

With support for expanded and extended memory, HiWIRE II can handle your most demanding schematic and PCB designs. The unique HiWIRE II editor allows you to display and edit schematics and PCBs simultaneously, using the same commands for each. HiWIRE II is $995 and is guaranteed.

WINTEK®
Wintek Corporation
1801 South Street
Lafayette, IN 47904
Phone: (317) 448-1903

1-800-742-6809

CIRCLE NO. 264

High-Resolution Medical Color Monitors

X-Med's 14" and 15" low-radiation super VGA monitors are listed to UL 544 medical standards, and feature patented low-leakage EMI filters. Other features include:

- Small footprint fits any desktop.
- Ergonomically designed screen controls with easy pincushion correction.
- Built-in autosizing and autocentering.
- Multiscanning to maximize resolution, picture quality and graphics card compatibility.
- State-of-the-art surface mount technology.

Contact us today for additional information and specifications on these outstanding new monitors.

X-MED SYSTEMS
X-Med Systems Division of Condor D.C. Power Supplies, Inc.
2311 Statham Parkway, Oxnard, CA 93033
(805) 486-4565 • FAX (805) 487-8911

CIRCLE NO. 234

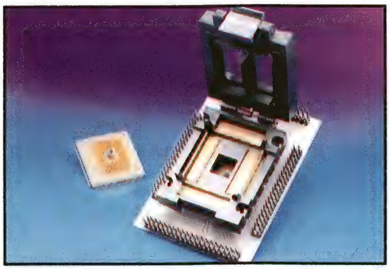
To advertise in Product Mart, call Joanne Dorian, 212-463-6415

4-Color Product Mart Ads Are Available in EDN Magazine and Products Editions!

For an additional $340, you can run your Product Mart Ad in color. For more information, call Joanne Dorian at (212) 463-6415.

CIRCLE NO. 268

TEST SMT QFP



IN ZIF SOCKET

The Ironwood line of **CARRIER ADAPTERS** allow probing of SMT QFP devices by simply mounting a **QFP EMULATOR FOOT** to the land pattern. The **SOCKET/PROBE** assembly is then plugged onto the FOOT with matching connector. Target IC is then inserted into ZIF socket for easy test/removal. EMULATOR FOOT is constructed for easy installation and reliability. Available in sizes from 44 to 208 pins.

IRONWOOD ELECTRONICS
P.O. BOX 21151, ST. PAUL, MN 55121
(612) 431-7025; FAX (612) 432-8616

CIRCLE NO. 249

PLDs, CPLDs, FPGAs...

for the best in Programmable Logic Design Synthesis Software to suit any budget, call:

MINC
INCORPORATED

800 755 3742

Tel: 719 590 1155 • Fax: 719 590 7330 • E-Mail: salesinfo@minc.com

CIRCLE NO. 253

MICROPROCESSOR EMULATORS

Zax provides a comprehensive series of real-time emulation support for Motorola, Intel, NEC, Zilog, and Hitachi microprocessors. Some of the highlighted features include source-level debug, real-time trace, and performance analysis.

Call now for more information:

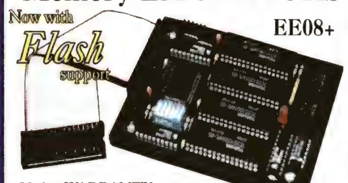
(800) 421-0982
(714) 474-1170 (Inside CA)
(714) 474-0159 (Fax)

ZAXTEK

42 Corporate Park Irvine, CA 92714

CIRCLE NO. 265

FLEXIBLE Memory EMULATORS



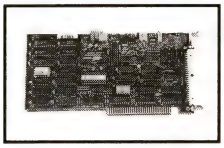
- 90 day WARRANTY.
- 10 day MONEY-BACK GUARANTEE.
- Supports Read and WRITE access by TARGET.
- Download and VERIFY from HOST.
- View/Edit SRAM contents while target is running.
- Full screen ASCII/HEX editor included.
- Libraries provide high level access to emulator.
- Daisy-chain up to 4 units for multi-EPROM targets.
- Field upgradable to 4Mbit (27040) emulation.
- Battery back-up, PLCC and 16bit adapters available.

Tech Tools
(214) 272-9392
FAX: 494-5814

Models start at $129

CIRCLE NO. 260

LOW-COST DATA ACQUISITION BOARDS



PCI-20428W. Because Your Customers Expect More for Less.

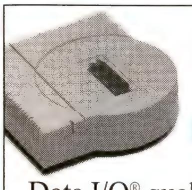
- OEM Pricing: from $249 (100's)
- 16SE/8Diff Analog Inputs, 100kHz (DMA)
- Gains (1), (1, 2, 4, 8) or (1, 10, 100)
- 2 Analog Outputs, 100kHz (DMA optional)
- 1 Counter/Timer; 2 Rate Generators
- 8 Digital Inputs, 8 Digital Outputs

(800) 685-9911
Fax: (602) 573-0522

INTELLIGENT INSTRUMENTATION™

6550 S. Bay Colony Dr., MS130 • Tucson, AZ 85706

CIRCLE NO. 247



2 New Versions!

ChipLab™

Data I/O® quality and reliability at a price you can afford.

- **ChipLab Memory/Micro** programs a broad range of memory and microcontroller devices for just $995*.
- **ChipLab Logic Plus** programs more than 1900 logic and memory devices for only $1495*.
- **Optional adapters** support PLCC, SOIC, QFP, and TSOP packages.

To order call **1-800-3-DataIO** Ext. 901
(1-800-332-8246)

*U.S. list price only.

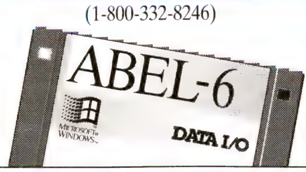
DATA I/O

CIRCLE NO. 235

NEW ABEL-6 for Windows: the easy way to design PLDs and CPLDs.

- Windows™-based interface is easy to learn and use
- ABEL™ Project Navigator simplifies the design process
- Full hierarchical support makes larger designs easier to manage
- Simulation waveform viewer lets you quickly, easily interpret results

To order call **1-800-3-DataIO** Ext. 602
(1-800-332-8246)



CIRCLE NO. 236

8051 68HC11 COP8 68HC05

iceMASTER® In-Circuit Emulators From $851

- Easy to learn & use
- Windowed interface--user configurable
- Real-time and non-intrusive
- Source level debug
- Support for structures, arrays, unions and pointers
- Trace buffer with advanced searching capabilities.
- Fast serial (RS-232) link to any PC, even laptops.
- Broad support of derivative devices/interchangeable probe cards
- Rental and 10-day trials available.
- Call today for free demo disk

(800) 638-2423

New DS80C320 8xL51Fx 8xC575

MetaLink® Corporation

Phone: (602) 926-0797
Fax (602) 926-1198

MetaLink Europe GmbH
Telefon: (08091) 2046
TeleFax (08091) 2386

CIRCLE NO. 252

To advertise in Product Mart, call Joanne Dorian, 212-463-6415

ELECTRIC VEHICLE MOTOR CONTROL

CURTIS/PMC, a division of Curtis Instruments, in business for over 30 years, is a world leader in the design and manufacture of transistorized and microcontroller based speed controllers, including applications for the industrial, recreational and invalid vehicle markets. This small, global company is currently seeking:

TEST ENGINEERING MANAGER Develop engineering qualification and production test strategies, specify equipment, schedule projects and ensure maintenance and update of existing equipment. Requires 8+ years' hands-on design or test experience in a product development environment, BSEE, expertise with computerized test equipment, analog and digital electronics and project management. Software and microcontroller systems experience helpful.

PROJECT ENGINEER Prepare product specifications and work with a team of multi-disciplined professionals in the design and development of motor control products. BS or MS in Electrical Engineering, five years of project leadership plus analog circuit design and microcontroller experience in a product development environment. Experience in power electronics and motor control for material handling vehicles highly desired.

MANUFACTURING ENGINEER Create and execute processes and methods for assembly and test manufacturing operations consistent with cost and design objectives. Resolve production problems with new and existing products, recommending design and assembly improvements. BSEE/BSME (or equivalent) plus previous experience in a design or manufacturing position with working knowledge of analog and microcontroller applications.

SENIOR ELECTRICAL ENGINEER Develop high power motor control products and specify motors for those products including series, separately excited and other industrial DC and AC motor controllers. BSEE plus 10 years' design experience in high power AC permanent magnet and series motor control electronics. Extensive experience in power electronics and devices. Experience generating specifications and leading teams of engineers and technicians.

We offer a competitive compensation package including employer-paid medical, dental, disability and life insurance, vacation, tuition assistance, profit sharing and a 401(K) retirement plan. Relocation assistance also provided. To apply, send or fax your resume specifying relevant technical background, in confidence, to:

Human Resources Department, CURTIS/PMC, 6591 Sierra Lane, Dublin, CA 94568. (FAX) 510-833-8777. Equal opportunity employer m/f/d/v.

CURTIS PMC
A DIVISION OF CURTIS INSTRUMENTS, INC.

FED
CORPORATION

FLAT-PANEL VIDEO DISPLAY CIRCUIT DESIGN PROJECT LEADER.

Requires strong background in digital circuit design and some mixed signal to design video controllers and matrix-addressed driver interfaces, working knowledge of mask layout, and exp. interfacing w/high density circuit board and IC mask vendors. BS or MS EE & min. 5 yr. exp.

We are an innovative high tech co. developing a new type of field emission flat-panel video display. Come grow with us in our world class mfg. site in the beautiful four season Hudson Valley.

Send resume to attn: VCD
FED Corp., 1580 Route 52, Hopewell Jct., NY 12533
(or FAX to: 914-892-1901)

(Additional mfg. and R&D positions open in areas of: IC process engineering, equipment, packaging, engineering management)

IOWA MIDWEST

RF/TELECOM — **WIRELESS**

NEBRASKA-MINNESOTA-ILLINOIS

I have immediate openings for Design Engineers and Technical Project Managers with BS/MS plus 3 to 10 years RF/Radio design experience in any of the following areas: RF circuit design (100 MHz to 3.0 GHz), Receivers, Transmitter Exciters, Low-noise Frequency Synthesizers, Power Amplifiers, Spread Spectrum Modulation, Digital Radio DSP. These positions are all with top non-defense companies in good Upper-Midwest locations

DON GALLAGHER, MSEE
Gallagher & Brei Associates
1145 Linn Ridge Rd., Mount Vernon, IA 52314
(319) 895-8042 • Fax (319) 895-6455

If you want to reach over 163,000 engineering professionals, in:

EDN Career Opportunities

Get the attention of 100% qualified engineers and managers involved in designing or developing electronic products, who look to EDN Magazine's Classified section for career opportunities.

Only EDN can guarantee you're reaching the key design engineers in the Electronic Original Equipment Manufacturer market.

For more information, contact:

Trish Kennefick
Tel: 1-800-603-4859
Fax: 1-617-630-3925

MYTH

To Compete In The Global Marketplace PC Companies Must Specialize.

MATH

At Dell, 7,500 Diverse Thinkers Enable Us To Succeed In Any Marketplace.

Focusing on a single narrow segment of the market is one way to make a fast start in the computer business. But specializing in only one area has some pitfalls as well. Dependency on a limited customer base can be risky. And a singular corporate mindset tends to restrict creative thinkers.

At Dell, we believe in having it all. That's why we've kept our spirited drive and innovation while providing the power of one of the largest PC companies in the world. Our cultural diversity enables us to draw on a broad, multinational experience. Plus, we make it a habit to ask our people what they think about every aspect of our business - and then we listen to what they have to say.

Dell didn't get to be a global player in the computer industry by playing follow the leader. If you feel stifled by the sameness of the computer industry, step out into a world where your ideas will be valued, and where the accent is on performance. Why not decide to have it all? Join the team at Dell.

ENGINEERING

512.728.9530 FAX
(Position Code PG)

- BIOS Programmers
- Software Engineers
- Product Marketing Managers
- Hardware Engineers
- Logic Designers
- Windows Programmers
- Technicians
- Network Systems Test Engineering Manager
- Senior Hardware Engineering Technicians
- Information Development Manager
- Monitor Engineer
- Video BIOS
- Program Manager
- Comms Engineer

MANUFACTURING DISTRIBUTION

512.728.9439 FAX
(Position Code WWOP)

- Manufacturing Manager
- Test Engineers
- Manufacturing Planner
- Industrial Engineers
- Buyers/Planners
- Quality Engineers
- Supplier Quality Engineers

To reply, contact us by fax or by mail, indicating position code and position desired.

DELL COMPUTER CORPORATION
Staffing Department, EDN111094
2214 W. Braker Lane, Suite D
Austin, Texas 78758

Workforce diversity is an essential part of Dell's commitment to quality and to the future. We encourage you to apply, whatever your race, age, color, religion, national origin, gender, disability, or veteran status.

Switch-product catalog. This 120-pg guide features a range of switches, including power rocker, pushbutton, and slide switches that are UL, CSA, and EURO approved. It highlights additional switches, such as toggle, tiny toggle, tiny slide, tiny pushbutton, DIP, piano DIP, DIP rotary-standard (BCD), autoinsert, and surface-mount. **Lamb Industries Inc**, Portland, OR.
Circle No. 367

Journal features test equipment for digital mobile radio. This 60-pg book contains articles and application notes on digital radio products. A refresher topic, "RF power measured the right way," is included. **Rohde & Schwarz**, Munich, Germany.
Circle No. 368

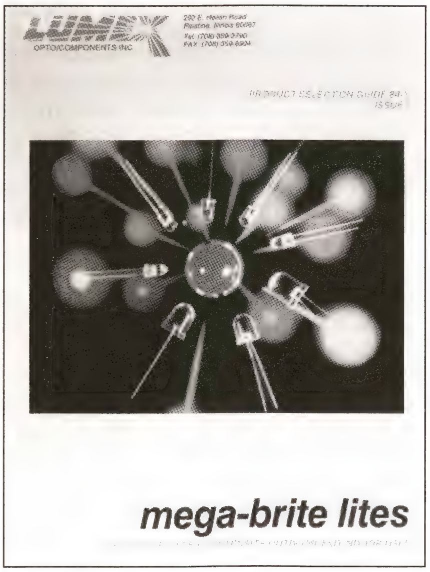
RF/IF designer's guide. This 127-pg catalog features product listings and specifications for a line of RF/IF and microwave components. Products include frequency mixers, power splitter/combiners, amplifiers, attenuators, terminations, directional couplers, and filters. **Mini-Circuits**, Brooklyn, NY.
Circle No. 369

Catalog details motion controllers. This 128-pg guide provides specifications on a line of motion controllers, including PC, VME, and STD bus cards. The catalog contains a 22-pg technical reference that provides an overview of motion-control systems and describes each element of a closed-loop system. A guide to motion programming, featuring engraving, pick and place, cut-to-length, rotating knife, and moving webs, is also included. **Galil Motion Control Inc**, Sunnyvale, CA.
Circle No. 370

Catalog for power components. A 36-pg catalog details a line of component and configurable power products. The guide includes photographs, product descriptions, selection charts, applications information, and pricing information. **Vicor Corp**, Andover, MA.
Circle No. 371

Gigabit link-analyzer demo disk. This free disk simulates the operation of the GLA-2000 gigabit link analyzer. The disk focuses on the functions and operations of the GLA and includes a tutorial. **Finisar Corp**, Menlo Park, CA.
Circle No. 372

Battery-holder guide. This guide provides specifications, features, and application information for a line of battery holders. The 23-pg guide includes three pages of application tips for various battery types, including general purpose, rechargeable, lithium, and NiCd. **Memory Protection De- vices**, Farmingdale, NY.
Circle No. 444



LED selection guide. A product selection guide features a line of very high intensity red, green, and yellow LEDs. The brochure includes electro-optical specifications, detailed dimensional drawings, and radiation-pattern graphs. **Lumex Opto/Components Inc**, Palatine, IL. **Circle No. 445**

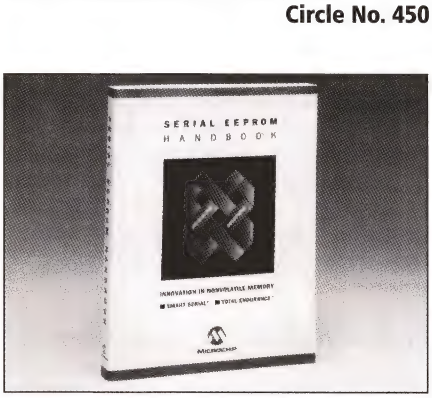
You and your electric motors. *How to get the most from your electric motors* helps plant-maintenance engineers maximize the operation and up time of their electrical equipment. The booklet provides information on maintenance, voltage, application, spare motors, and repair vs replacement. **Electrical Apparatus Service Association Inc**, St Louis, MO. **Circle No. 446**

Guide for freebies on Internet. *Free $tuff from the Internet* provides step-by-step instructions on how to get free merchandise including catalogs, coupons, product samples, newsletters, software, photos, art, music, and video clips. The book features "The Tightwad's Guide to Mosaic," a hands-on guide to Mosaic and the World Wide Web. $19.99. **The Coriolis Group**, Scottsdale, AZ. **Circle No. 447**

Catalog details switches. This 110-pg book features rocker, slide, push-button, and sealed toggle switches. The guide provides specifications, materials, and terminations information. **E-Switch**, Minneapolis, MN.
Circle No. 448

Engineering bulletin features plastic dielectric trimmer capacitors. *Engineering Bulletin SG-402F* highlights a line of plastic dielectric trimmer capacitors. The bulletin details features, specifications, available modifications, photographs, and outline drawings for each series. The dielectrics offered include PTFE, polypropylene, polycarbonate, and polyimide. **Sprague-Goodman Electronics Inc**, Westbury, NY. **Circle No. 449**

PC-based test-solutions source book. A product catalog lists hardware, software, and system products for PC-based ATE, data-acquisition, and test-and-measurement applications. The 40-pg guide includes specifications, selection charts, block diagrams, and configuration and application suggestions. **Geotest Inc**, Irvine, CA.
Circle No. 450



EEPROM handbook. The *Serial EEPROM Handbook* serves as a reference guide for a line of EEPROMs. The 480-pg book contains product specifications, application notes, and qualification reports on a line of memory products and tools. **Microchip Technology Inc**, Chandler, AZ. **Circle No. 451**

Brochure on signal devices. A 12-pg brochure describes the Mallory Sonalert audible signal devices. A section detailing design information such as mounting method, case style, frequency, minimum sound pressure, operating current, and voltage is included. **North American Capacitor Co**, Indianapolis, IN.
Circle No. 452

Brochure on network analyzers. This free brochure provides information on measurement-accuracy sources and optimum network-analyzer configuration for test systems covering RF, microwave, and millimeter-wave applications. The pamphlet covers sources of measurement accuracy and uncertainty for common transmission and return-loss measurements. **Anritsu Wiltron**, Morgan Hill, CA.
Circle No. 453

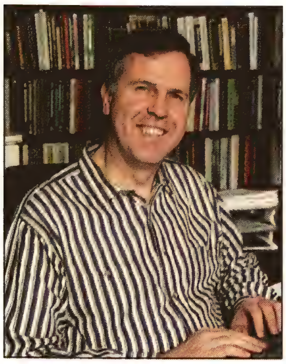
Handbook features principles and applications for photomultiplier tubes. A handbook describes the operating principles of the photomultiplier tube and its applications in medical imaging, high-energy physics, and cosmic-ray research. Designers can obtain information on operating principles and construction, operating characteristics and considerations, and nonscintillator applications of the device. **Philips Components**, Slatersville, RI.
Circle No. 454

Free interactive boundary-scan tutorial. This free tutorial is available as a disk-based Windows file. Topics include how boundary scan works, different types of test philosophies, approaches to pc-board design, test-program generation issues, and how to integrate boundary scan within a computer-aided concurrent-engineering environment. **Schlumberger Technologies ATE Div**, Wimborne, Dorset, UK. **Circle No. 455**

Profiling products and technologies for maintenance programs. A 32-pg catalog highlights inspection instruments for a variety of industries. It features descriptions and specifications of products and supportive technologies. The products include leak detectors to monitor toxic gases, ultrasonic thickness gauges, a reference leak to calibrate leak detectors, combustion analyzers, and confined-space monitors. **EPD Technology Corp**, Elmsford, NY. **Circle No. 456**

Ceramic-trimmer capacitor catalog. An eight-pg guide to ceramic-trimmer capacitors describes six size types with maximum capacitances ranging from 2 to 40 pF. The catalog features a line of prototype kits and tuning tools. **Voltronics International Corp**, Denville, NJ. **Circle No. 457**

*Advertiser in European edition



DAVID BRUBAKER,
FUZZY-LOGIC
CONTRIBUTING EDITOR

Dismantling a fuzzy rule-based system shows its inner workings

Stop me if you've heard this one. The French Revolution is in full swing. The government has condemned three people—a physician, a lawyer, and an engineer—to the guillotine. As a statement of their innocence, all three elect to lie on their backs, facing upward. The lawyer goes first. As the blade falls, it snags and stops six inches above his neck. The convention is that a guillotine malfunction indicates divine intervention, and the lawyer goes free.

The executioner makes a few adjustments, and it is the physician's turn. Again, the blade stops short, and the physician also goes free. Now somewhat frustrated and perhaps out of his league, the executioner again fiddles with the guillotine. The engineer is strapped in place, facing upward. Just before the blade is released he calls out, "Wait a minute. I think I see your problem."

Engineers are problem solvers who want to see devices work correctly and work well. Most of us also need to know how things work.

We engineers are problem solvers. We want to see devices work correctly and work well. Most of us also seem to have a need to know *how* things work. As children, we took apart motors, radios, the family television set, and anything else we could lay our hands on. When we retire, we will tinker.

This month, we will set aside the theory and philosophy and take apart a fuzzy rule-based system to see, component by component, how one actually works.

For our purposes, "degree of membership" and "truth value" mean much the same thing. A 5-ft, 8-in. woman as a member of the set "tall women," which has a degree of membership of 0.80, is identical to the statement "A 5-ft, 8-in. woman is a tall woman" being true with a truth value 0.80. Keeping this in mind will help you wade through the following.

A fuzzy rule-based system includes three sections: the fuzzification step, or fuzzifier, which converts crisp input values into degrees of membership in fuzzy input sets; the inference step, or rule base, which determines from input conditions the actions to take; and the combination/defuzzification step, or defuzzifier, which combines multiple fuzzy actions and determines a single crisp executable output.

A fuzzy controller for a motor that drives the flow of a fluid provides an example to show the operation of each component. The controller has two sampled inputs, the motor's rotational velocity, ω, and the fluid's flow-rate error, ϵ, which is the difference between the actual and the commanded flow rates. The controller has one output, the motor-drive current, I_d. The example is incomplete and intentionally artificial because I want to concentrate on how the fuzzy system works and not on what it is doing.

Fuzzification

Let's first discuss the fuzzifier in terms of the input, ω, a crisp input with values ranging over $0\omega \le \omega \le 2000$ rpm. Because this is a fuzzy system, we will work with the fuzzy, or linguistic, values of the fuzzy input Rotational_Velocity. The system designer assigns these fuzzy values and gives them labels, such as Near_Zero, Very_Low, Low, Medium, High, and Very_High. Each of these labels represents a fuzzy set in the operational domain of possible crisp values (**Fig 1**). You can consider each set a (fuzzy) value of the (fuzzy) variable Rotational_ Velocity. You can define each set as a membership function, with domain (its "x-axis") over the possible crisp values and range (its "y-axis") from 0 to 1.

Actual measured values are crisp (for example, 1025 rpm). You express rules using fuzzy terms, such as "if Rotational_Velocity is High then..." You perform fuzzification, or transformation from crisp to fuzzy values, by identifying to what degree the crisp value is a member of each of the fuzzy sets.

PHOTOGRAPHY / LIANE ENKELIS

You typically use the label μ, ranging in value over $0 \le \mu \le 1$, to represent this calculated degree of membership. You calculate the degrees of membership of a crisp-input value directly from the (membership) functions that represent the fuzzy sets.

For example, ω=1025 rpm results in a degree of membership of 0.69 in the set High, or

$$\mu_{High}(\omega=1025)=0.69.$$

For successful operation of a fuzzy system, input membership functions overlap. The fuzzy set Very_High, therefore, also contains the same crisp value, ω=1025, or

$$\mu_{Very\_High}(\omega=1025)=0.31.$$

It has zero membership in all other sets (**Fig 2**). You now apply these degrees of membership as truth values to the conditions of rules in the inference step.

Rules

In rules, you express both conditions (antecedents) and actions (consequences) as fuzzy terms, most often in the form "if (condition) then (action)." An example is

IF Rotational_Velocity is Medium
AND
Flow_Rate_Error is Positive_Large
THEN Drive_Current is Med_Large;.

You calculate the degree to which each of the conditions is true as part of the fuzzification step and apply these as inputs to the rule base. If a rule contains several conditions linked by one or more logic operators, you use fuzzy-logic operators to combine the respective truth values. Fuzzy-logic operators, such as AND, OR, and NOT, are conceptually the same as bilevel logic operators, but you define fuzzy-logic operators differently. If you have two fuzzy truth values, μ_A and μ_B, you could define AND, OR, and NOT as:

$$\mu_A \text{ AND } \mu_B=\min(\mu_A, \mu_B)$$
$$\mu_A \text{ OR } \mu_B=\max(\mu_A, \mu_B),$$
$$\text{NOT } \mu_A=1-\mu_A$$

as Professor Zadeh originally defined them. Although others have proposed and used other fuzzy operators in various systems, the "Zadeh operators" are still the most popular. When μ_A and μ_B are either 0 or 1, these definitions are the same as the Boolean operators.

Any rule that has a nonzero value for its condition has "fired." Because of overlapping input membership functions, more than one rule often fires at a time. You do this to achieve smooth output transitions between regions where a single rule fires. Now comes a key to how a fuzzy rule base works. *The strength of the firing of each individual rule is the degree to which its conditions are true; you apply this strength as a truth value to the action or actions the rule indicates.* If a rule fires weakly, the action it specifies only weakly impacts the subsequent system output. If the rule fires strongly, that rule's action greatly affects the system output.

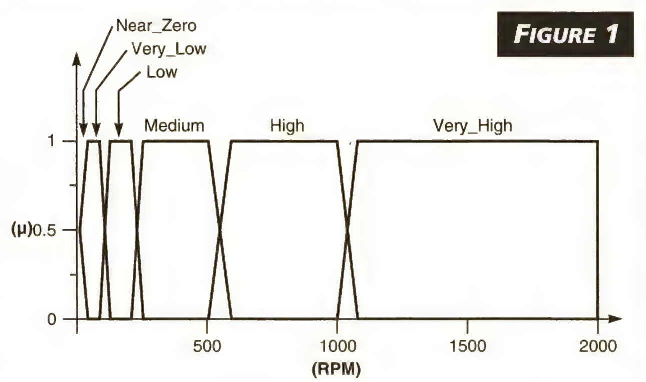
In the rule above, let "Rotational_ Velocity is Medium" have a truth value of 0.69; that is, the crisp rotational velocity input, ω, is a member of the set Medium with 0.69 degree of membership. Also, let "Flow_ Rate_ Error is Positive_Large" have a truth value of 0.35. The truth value of the rule's condition is the AND of the truth values of the two expressions and is, therefore, the minimum value, 0.35. Because this value is nonzero, the rule has fired, and the truth value of the condition is applied as the truth value of the action "Drive is Med_Large" receives the truth value 0.35. We use this value in the combination/defuzzification step.

Combination/defuzzification

Each rule that fires at each system iteration specifies its own action. A degree of membership in an output fuzzy set now represents each fuzzy action. **Fig 3** shows what the output sets for the Drive_Current output in our example might be.

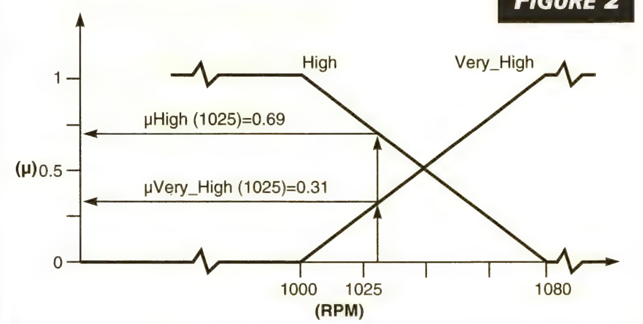
Two steps remain to determine the crisp, executable system output: combining all fuzzy actions into a single fuzzy action and transforming the resulting single fuzzy action into a crisp, executable system output. A single rule's firing requires no combination step, only defuzzification. Also, you can perform combination

FIGURE 1



When you treat a variable as being fuzzy, its values are also fuzzy. Although the fuzzy system measures a crisp input value of 1025 rpm, it is more interested in whether and to what degree the measurement is High or Very_High.

FIGURE 2



A measured value of 1025 rpm belongs to both High and Very_High sets. Solving the respective membership function determines the degree to which the value belongs to each set. Thus, for ω=1025, Rotational_Velocity is said to be High with degree of membership of 0.69 and Very_High with degree of membership of 0.31.

books that work the way you work

Analog Circuit Design:
Art, Science, Personalities

Jim Williams, Linear Technology Corp., Editor

"If you do any analog circuit design, buy this book!...The well-indexed volume ... provides a picture of analog design, in all its diversity, as a way of thinking and a way of approaching problems."

Dan Strassberg, EDN

1991 352pp. clth 0 7506 9166 2 $44.95 (£30.00)

Based on the EDN Series, with 20% NEW material

Troubleshooting Analog Circuits

Robert Pease, National Semiconductor

"Here's a chance to take advantage of [Pease's] years of experience designing analog circuits--and working the bugs out of them. This book is for you whether you're designing analog circuits at the board, box, system, or IC level." ***Electronic Design***

1991 208pp. cloth 0 7506 9184 0 $32.95 (£19.95)

Loaded with practical information

Rechargeable Batteries Applications Handbook

Technical Staff, Gates Energy Products

This is a comprehensive reference on proper selection, specification and application guidelines from one of the world's largest sealed-cell manufacturers. *May 1992 432pp. cloth 0 7506 9227 8 $49.95 (£38.50)*

The EDN Series for Design Engineers

In the U.S.
for more information
or to place an order call
1-800-366-2665
M-F 8:30-4:30 E.T.
Fax 617-279-4851

In Europe, order from:
Reed Book Services Ltd.
Special Sales Department
P.O. Box 5, Rushden
Northants NN10 9YZ U.K.
TEL. 0933 58521 FAX 0933 50284
Please quote "Cahners 13.89"

BUTTERWORTH-HEINEMANN
80 Montvale Ave., Stoneham, MA 02180

VISA MasterCard

CAHNERS 13.89

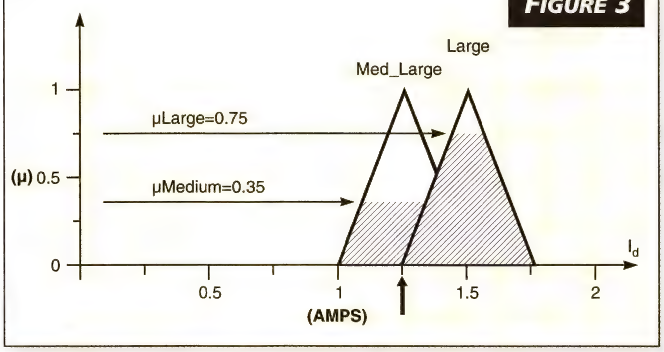
and defuzzification in either order or simultaneously.

The most popular combination/defuzzification technique is the "center-of-mass," or "centroid," technique in which each rule action specifies an output fuzzy value (such as "Drive_Current is Large") and a strength (the indicated truth value). In the centroid method, you top the membership function representing each fuzzy value at the value of the truth value, μ, with which the rule fired. You calculate the center of mass (centroid) of each resulting area and determine the center of mass of these centers of mass. The centroid of the combined areas defines the crisp, executable output (**Fig 4**).

You can most easily visualize this process by treating areas as rigid sheets that are glued together. The center of mass of the resulting collection of sheets, the point at which it will balance, identifies the crisp output value to execute.

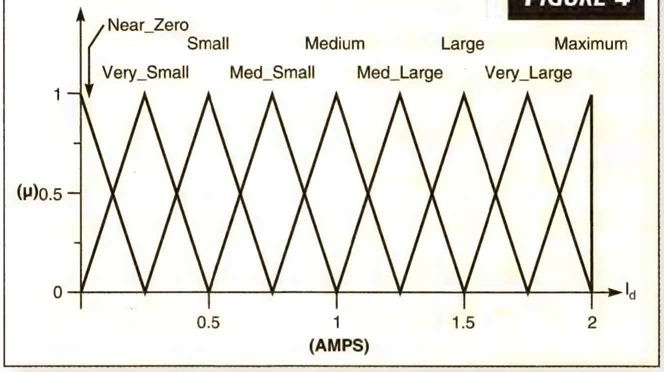
The truth value of each output is not the strength with which it executes, but rather a weight in the combination process. In our example, if a single rule were to fire, the executed output would be the same, regardless of the strength with which it fired. This is because the centroid of a vertically symmetric output membership function is independent of the level at which it is lopped off.

FIGURE 3



You can also define fuzzy actions linguistically and represent them as membership functions in the output space, in this case, over the range of possible drive currents.

FIGURE 4



If two triggered rules specify output actions of "Drive_Current is Med_Large" (μ=0.35) and "Drive_Current is Large" (μ=0.75), the centroid method of defuzzification lops the tops off the respective membership functions at the specified μ and then finds the center of mass of the centers of mass of the resulting areas. This is the same as treating the indicated regions as two metal plates, glued together and locating the balance point. In this example, the defuzzified output, which will execute, is approximately I_d=1.23A (heavy vertical arrow).

To summarize, a fuzzy-rule-based system is a sampled data system that maps inputs to outputs through rules. The system samples inputs at each sampling interval and applies those inputs to the appropriate input membership sets to determine their degrees of membership in each set. This step is fuzzification.

You express how a system operates by its rules, typically using an "if-condition-then-action" format. The degrees of membership of inputs in fuzzy input sets are the rule conditions. You also express rule actions as fuzzy sets. The truth value of an action is the degree to which the corresponding input condition is true. You can logically combine multiple expressions into a condition using fuzzy-logic operators. Scanning the rule base for a set of inputs is the inference step.

When several rules fire at once, as is often the case in a fuzzy system, their actions must combine into a single action. In addition, because you express this single action as a combination of fuzzy sets, you must convert it back into a crisp executable output. This final step is combination/defuzzification, or, simply, defuzzification. This fuzzify-infer-defuzzify sequence executes at each system time increment for each new set of system inputs, each time generating a set of executable outputs. That is how a fuzzy-rule-based system works.

When I first told the guillotine joke to my family, my then-five-year-old daughter asked if the engineer also went free. I would like to think so, but probably not.

To close, I have two administrative announcements. First, starting next year I will intersperse the normal tutorials, application discussions, and tool reviews with an occasional question-and-answer exchange. You readers will be the source of questions. Please send them to me directly using either the postal address or electronic-mail address indicated below.

Second, I am attempting to respond to all who send in comments or questions and will continue to do so unless the numbers involved make it impossible. On several occasions, my response to an e-mailed message has been returned with the Internet equivalent of "addressee unknown." For those of you who correspond via e-mail, please include your postal mailing address; if my electronic response bounces, I will mail it to you. For those of you who have sent e-mail to me and have not received a response, please send it again and include your postal address.

David Brubaker is a consultant in fuzzy-system design. You can reach him at Huntington Advanced Technology, 883 Santa Cruz Ave, Suite 31, Menlo Park, CA 94025-4608 or on the Internet at: brubaker@cup.portal.com.

Interpoint's MIL-STD-883 dc-dc converters:

Recognized for outstanding performance.

On Space Station Freedom, the Patriot
ssile, European Fighter Aircraft and
ousands of critical applications,
terpoint dc-dc converters are the ones
signers choose first. However you
easure performance, Interpoint com-
ands the field.

REL DC-DC Converters for Every Power Level

SA	16 to 40	5,12,15	1 or 2	5 W
HF+	16 to 40	5,12,15	1 or 2	15 W
TR	16 to 40	5,12,15	1, 2, or 3	30 W
FL	16 to 40 160 to 400	5,12,15,28	1 or 2	65 W*
FLHP	19 to 40	5,12,15	1 or 2	100 W*

ultiple units current share

Interpoint is recognized for broadest selection. From fully qualified SMD parts to low-cost solutions, from 5 to 285 watts. Interpoint has a solution for almost every power need.

Interpoint is recognized for innovation. Our 20-year history of breakthroughs includes the first 70 W/in^3 board-mountable dc-dc converters.

Interpoint is recognized for reliability. Our power supplies have logged more than 1,000,000 field hours per failure.

Our new, fully compliant MSA Series offers 5 watts of power in a case just 0.27" high. The MSA also meets MIL-STD-704A input voltages (up to 80V surges) with 5, 12, and 15 Vdc outputs.

CIRCLE NO. 137

For your **FREE HI-REL DESIGN FIELD KIT,** with Guides to selecting and using dc-dc converters in HI-REL systems, call:

1-800-822-8782

NEW! The 30-watt MTR Series now meets MIL-STD-883

In Europe, contact:

Interpoint, Ltd
Victoria House
18-22 Albert Street
Fleet, Hampshire
United Kingdom GU13 9RL
Phone: 44-252-815511
Fax: 44-252-815577

Interpoint Sarl
2-4 Boulevard de la gare
95210 Saint Gratien
France
Phone: 33-1-34-28-54-55
Fax: 33-1-34-28-23-87

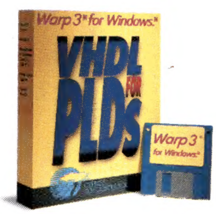
interpoint

GET THE POWER AND THE GLORY.

AND BRING A MORE ENLIGHTENED APPROACH TO PROGRAMMABLE LOGIC.

Here's a revelation for everyone designing with CPLDs and FPGAs.

Warp3™ is the easiest way into VHDL and the fastest design path for high-density programmable logic: from creation through optimization. *Warp3* is based on ViewLogic's™ highest-end Powerview™ and Workview Plus™ graphical environment for Sun and PC platforms. Now you can reevaluate designs in minutes–not hours–with automatic place and route and fitting. Enjoy full timing simulation, mixed mode design entry and schematic capture. Designs can be targeted to Cypress's UltraLogic™ family of high-performance pASIC380 FPGAs and high-density FLASH370 CPLDs, or to alternate devices without modification. Try it for yourself. And see the light.



For a free demo disk and brochure call in Europe: (32) 2-652-0270, ext 119*, Dept C4H.

Or contact us via Europe and Asia fax and telephone numbers listed below. *The international operator can give you your country's specific access code.

ULTRA LOGIC

Europe: Fax (32) 2-652-1504. Telephone Hong Kong: (852) 710-8121. India: (812) 566-630 x-3808. Japan: (81) 423-69-82-11. Korea: (82) 2-576-2111 or (82) 2-888-2858. Singapore: (65) 294-8389. Taiwan: (886) 2-820-53-53. *Warp* and UltraLogic are trademarks of Cypress Semiconductor , 3901 North First Street, San Jose, CA 95134 Phone 1-408-943-2600.

CYPRESS